Shelve Publications

PUGET SOUND
MARINE STATION
PUBLICATIONS

Volume 1
1915-1917

PUGET SOUND MARINE STATION
PUBLICATIONS

Mail addressed to the Puget Sound Marine Station often is confused with that for the United States Navy Yard or for the United States Naval Training Station. For that reason it is necessary to change slightly the name of the series. Future numbers will therefore appear as the *Publications of Puget Sound Biological Station* of the University of Washington.

Contents of Volume 1

CORRECTIONS

Page 3, line 7; for "a half inch" read "2½ inches."

Page 5, line 10: for "seleced" read "selected."

Page 10, line 21: for "zoosporeangium" read "zoosporangium."

Page 19, line 11: for "was" read "has"; also line 31, for "*laryx*" read "*larix.*"

Page 37, line 7, and thruout this article: for "*Haemigrapsus*" read "*Hemigrapsus,*" and for "*chiragonus*" read "*cheiragonus.*"

Page 74, line 2; "*plants*" should be in Roman type.

Page 79, number 64; for "Nereocystic" read "Nereocystis."

Page 85, line 20; for "undertakeng" read "undertaken."

Page 86, line 35; after "Peters" put the exponent 4.

Page 87, last line; for "to" read "of."

Page 119, line 13; "Novae Zelandiae" should be in italics.

Page 137, lines 3-4, 27; "*Laminariaceae*" should be in Roman type; line 15, for "form" read "forms."

Page 138, line 25; after "pests of" insert "the kelps. The hold-fasts were left on the plants for convenience in attaching them."

Page 139, at bottom of page, as footnote, insert "*Young plants."

Page 140, line 35; for "blade" read "blades."

Page 141, line 14 below table; for "bast" read "base."

Page 142, line 14; "*Laminariaceae*" should be in Roman type.

Page 148, lines 2 and 11; for "*costata*" read "cordata."

Page 167, table 5, line 2; for "all dead" read "all alive": line 3; for "all alive" read "all dead": line 11, just above "Flat short crab," for "Lophopanopeus bellus" read "Petrolisthes eriomerus."

Page 168, table 6, line 5; for "edulus" read "edulis": line 11; for "sanguinolentia" read "sanguinolenta": line 17; for "tessalatus" read "tesselatus."

Page 169, last line; elevate "Cancer oregonensis Dana" to the second line from the bottom.

Page 170, table 8, line 9; for "No response" read "Recovered": line 10; remove "Recovered."

Page 176, line 42 should be just below line 27, beginning "purpura," and should read
"Terebratalia obsoleta Sow. |Brachiopod | 2 2 2 2 2 1 1 r"

Also line 49 should be just below line 62, beginning "Rhinolithodes," and should read

"Terebratulina unguicula Carp. |Brachiopod | | | | | | | |2|2| | |r"

Also line 56 should be just above line 63, beginning "Dermasterias," and should read

"Hemithyris psiltacea Gmel. |Brachiopod | | | | | | | |2|2|2|1|r"

Also line 64; for "leyiuscula" read "leviuscula."

Page 192, last line; *"Laminariaceae"* should be in Roman type.

Page 203, last line of footnote; for "33" read "34."

Page 210, summary, No. 3; for the third line substitute "the above line, exposed to sun, wind and waves, and the presence of strong."

Page 216, citation No. 3; just before the volume number insert "Mitteilungen a. d. zool. Station zu Neapel."

Page 223, line 14; "Ulva" should be in italics. Lines 15-16; *"Phodochytrium"* should read *"Rhodochytrium."* Line 39; for "300 spores" read "zoospores."

Page 239, line 3; for "42" read "43."

Page 241, line 7; for "by Fig. 2" read "in plate 44."

Page 247, line 8; for "20" read "30."

Page 250, line 1; for "36" read "37."

Page 251, line 10; for "255" read "254."

Page 257, line 8; for *"artica"* read *"arctica."*

Page 259, line 4; for "of" read "with."

Page 282, Mesogloia, line 4; for "cm." read "dm."

Pages 285, line 21, and thruout this article; for *"Haplogaster mortensii"* read *"Hapalogaster mertensii"*: line 22, and thruout this article; for *"wossnessenskii"* read *"wosnessenskii."*

Page 302, line 8; "mandtii" should be in italics.

Page 311, line 8; for "correspondingly" read "corresponding."

Page 312, paragraph 12, line 1; for "—0.09" reda "—0.9."

Page 314, line 18; for "one" read "none."

Page 316, lines 9-10; for "prolongd" read "prolonged."

Growth of the Fronds of Nereocystis Luetkeana

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Concerning the growth of the fronds of *Nereocystis* very little has been carefully and accurately determined. Particularly concerning the rate of growth and just where in the frond the growth occurs, very insufficient information of any certain nature can be found. Frye (1) reports that the growth of the plant is very rapid and more especially in the spring. However, no statement is made with regard to the growth of the fronds alone, only with regard to the growth of the plant as a whole. In the same way Setchell (2, 4) speaks of the size of this kelp and its rapid growth, but gives no definite record of the growth of the fronds alone. It was for this reason that during the summer of 1914 at the Puget Sound Marine Station at Friday Harbor experiments were undertaken under the direction of Dr. T. C. Frye, to determine if possible some of these facts with certainty.

The experiments were carried on in four different beds of *Nereocystis* off the coast of San Juan and Brown Islands. Strips of white cloth marked with different colors and numbers were used in labeling. Observations and measurements were taken from day to day. The first experiment was to find out whether the plants would grow if detached from the rocks at the bottom of the water, and the effect upon the fronds of the removal of parts or all of the stipe. Setchell (4) says: "The Laminariaceae, like other fixed algae, depend upon a firm foothold, and are found affixed to rocks, stones, shells, wood, iron, and to other large algae. * * * * While some of the kelps, like *Macrocystis, Pelagophycus, Nereocystis, Alaria fistulosa*, etc., float for long distances, they make no growth except when attached, and perish when torn away from their substrata."

To test this inability of *Nereocystis* to grow when torn from its attachment, plants were loosened from the rocks, shells, or whatever the holdfast had been attached to, and tied to the bulbs of naturally anchored ones. Otherwise they were left freely floating. The conditions under which they were left were various. Some were left attached in their natural condition; others were pulled loose and anchored by the holdfast; from others three feet of the basal portion was removed; from some rather young plants more than half the stalk was removed; from other plants

the stripe was cut off just below the bulb, and a cork fitted into the opening to prevent the water from getting into the bulb; on some a mere fringe of the bulb was left at the point from which the fronds were growing and to which an anchoring string could be attached; from some the fronds were cut off close to the bulb and anchored to a raft. In all these cases the part of the plant experimented with remained healthy and grew apparently as well as the firmly anchored plants. Table 1 shows the first three measurements of such plants, taken within nine days.

TABLE 1. *Showing growth of laminae of free floating plants.*

Attachment of Plant	Original length; July 1	Length			Daily rate of growth
		July 3	July 7	July 9	
Naturally on rocks at bottom of bay	12″	15″	22.5″	26.25″	1.81″
Whole plant with holdfast tied to naturally attached plant	3′	3′ 3.5″	4′ 2″	4′ 6″	2.25″
Basal three feet of stalk removed, remainder tied to other plant	2″	2.25″	2.625″	3″	.125″
More than half of stalk* removed, remainder tied to other plant	1.5″	1.75″	2.25″	2.875″	.175″
Stipe cut off below bulb, remainder corked and tied to other plant	12″	13″	18.75″	23″	1.375″
Mere fringe of bulb left at frond base, tied to other plant	12″	14.5″	21.5″	——	1.6″
All of stipe removed, fronds anchored to raft............	12″	17″	21.25″	26″	1.75″

*Young plants.

The plants grew at rather a rapid rate, varying with the length, from one eighth of an inch to two and one fourth inches daily. We concluded therefore that for convenience at least part of the work could be done on kelps attached to a raft free from the entanglement of other kelp in a large bed.

TABLE 2. *Showing growth of different lengths of fronds left attached to bulbs.*

Date of Measuring	3-foot lengths	2-foot lengths	12-inch lengths	6-inch lengths	1-inch lengths*	1-4-inch lengths*
June 28th			12″	6″	1″	.25″
29th		2′	13″		1″	.25″
July 1st	3′	2′ 2.5″	15.75″	7.5″	1.125″	.25″
3rd	3′ 3.5″				1.25″	.1875″
7th	4′ 2″	3′	27.3″	12.8″	1.5″	.125″
9th	4′ 6″	3′ 3″	30.6″	15″	1.75″	.125″
11th	4′ 11″	3′ 6″	32.7″	17.166″	2.125″	.125″
13th	5′		38″	19.75″	2.25″	.125″
15th			41.75″	22.5″		
21st		5′ 2.5″	49.25″	31.833″	3.25″	.0625″
Average daily growth	2″	1.75″	1.62″	1.13″	0.0978″	—.0081

*Young plant.

The effect upon growth of cutting the frond tips shorter and shorter is shown in Table 2. The table shows an average of about ten plants of each different leaf length experimented upon. Healthy kelps were selected and the fronds cut to a length of three feet. These increased in twelve days to an average of five feet in length with a rate of growth of two inches each day. Those cut two feet long grew in twenty-two days to be five feet and a half inch long, with an average daily rate of growth of one and three fourths inches. Some of those cut to twelve inches long grew in twenty-three days to be fifty-three inches in length, and had an average daily growth of one and sixty-two hundredths inches. The six-inch frond grew to an average length of thirty-one and eighty-three hundredths inches in twenty-three days, with an average daily growth of one and thirteen hundredths inches. A later measurement of one of the six-inch fronds was made on Aug. 1, and in spite of the frayed end, the frond measured sixty-seven and a half inches, showing a growth in that one frond from a length of six inches to that of five feet seven and a half inches in thirty-four days. Only in young plants did growth take place when the fronds were cut to within an inch of the bulb. These grew to an average length of three and one-fourth inches in twenty-three days, and grew nearly one tenth of an inch daily. In no case was growth found to occur in the lower, firmer, more rounded portion of the frond below the flattened expanded part. Therefore no record is given in the table of the larger plants in which this basal part was more than an inch long. Only in the younger plants was there any growth to record for the first inch. No perceptible growth was found to occur in this stalked part in any of the observations, even though the rest of the frond was not removed. The shrinkage in the last column of Table 2 seemed to be due to loss of turgidity. A very slow growth, too slow to measure under the conditions, must take place there as in the bulb, since in old kelps the rounded bladeless basal part of the fronds is slightly longer than in the younger ones. If rapid growth did take place here, we would find these stalks much elongated, which is never the case.

From Table 2, we note the different rates of growth and the increase in rate with the increase in length of the frond. This clearly shows that growth extends for some distance up from the base. Setchell (4) says: "All kelps have physiological regeneration of the blade to a greater or less degree. The blade disintegrates and is worn away above and is renewed at the base at the same time that the stipe is increasing in length at the upper end. This process is continuous during the season of growth." This is all true, but there is a question concerning how much of the frond may be considered as base.

To determine just where the growth takes place a number of experiments were performed. For example the first two feet of two healthy fronds were removed from the stipe, cut into three-inch sections, and tacked by a single tack at the center of each piece, to a raft floating in such a way that they were held about an inch under the surface of the water. The ends were slipped under two narrow strips of cloth tied around the board, which helped to hold them in place. Plate 1 will explain the contrivance better. At the same time two feet of another
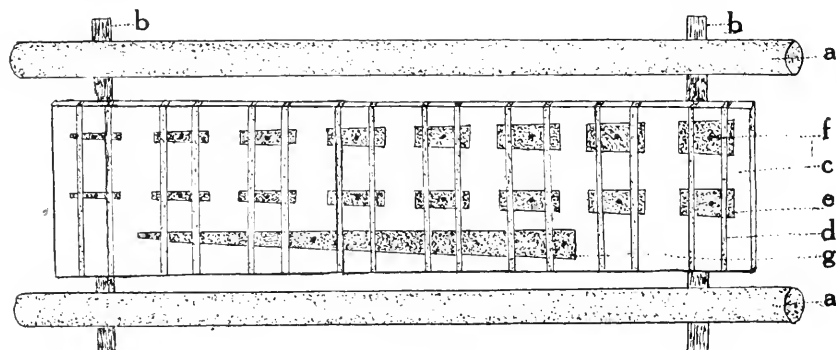
PLATE I.

a, pole about 4 inches in diameter; *b*, wooden strips; *c*, board 1 inch thick; *d*, strip of cloth; *e*, short piece of lamina of *Nereocystis; f*, carpet tacks; *g*, long piece of lamina *Nereocystis*.

frond was attached whole at one side of the short pieces. Table 3 shows the results of growth. The increase in the two-foot piece was greater than the added growth of the two feet of the three-inch pieces. This was to be expected since a number of the growing cells would be destroyed in cutting; also the "shock" to the plant would probably be greater and not so quickly overcome. Some of these pieces were left until they had reached more than double their length. Growth was found in each of the pieces, even to the last one of the two feet.

TABLE 3.   *Showing relative length in inches of 3-inch sections of fronds attached to raft.*

Dates	July 8	July 9	July 11	July 15	July 20
1st 3-inch piece	3	3.125	3.25	4.25	6.625
2nd 3-inch piece	3	3.375	3.625	6.5	*
3d 3-inch piece	3	3.375	3.625	*	*
4th 3-inch piece	3	3.375	3.5	5.375	7
5th 3-inch piece	3	3.125	3.375	5	6.5
6th 3-inch piece	3	3.1825	3.375	*	*
7th 3-inch piece	3	3.1825	3.25	3.3125	*
8th 3-inch piece	3	3.0625	3.1825	3.3125	4
24-inch piece	24	27.5	35.	43.	51.5

*Pieces lost off the raft.

It was interesting to note the growth of that part of the frond in which there were reproducing patches. Since it is concluded that the greatest growth is in the basal two or two and a half feet, and the reproducing patches seldom occur near the base of the frond, little growth takes place in that portion. Several fronds containing reproducing patches in various stages of development were marked, and results show growth there the same as in any other frond up to the time when these patches are about ready to drop out. About that time the frond appears to cease growing in the reproducing region and beyond, and often becomes torn.

Another frond was now selecced that was seven and one fourth feet long. This was marked by small holes punched down the center of the frond three inches apart, and the spaces between the holes measured from time to time. When it was found that this scheme worked out all right, the same experiment was performed on nine other healthy mature fronds taken from different plants, to verify the first results. Table 4 shows the average growth in inches of the ten laminae in each successive 3-inch portion, beginning at the base and numbered from one to twenty-seven. The measurements were taken two days apart, beginning July 19. It will be observed from the table that most of the growth occurs in the basal two feet; that nowhere beyond two and a half feet is the increase in the twelve days more than half an inch. The place of greatest growth is the second three inches, showing an increase of fifteen and a half inches.

TABLE 4. *Showing in what part of frond there is the greatest growth.*

In s from base.	Length	3d Day	5th Day	7th Day	9th Day	11th Day	13th Day
1	3	3.625	4.125	5.25	6.375	7.	8.25
2	3	5.	7.25	9.75	13.25	16.25	18.5
3	3	4.5	6.25	7.5	8.25	8.75	9.5
4	3	4.	4.5	5.25	5.75	6.25	7.5
5	3	3.75	4.25	4.75	4.875	5.25	6.375
6	3	3.75	4.25	4.5	4.625	4.875	5.
7	3	3.625	3.75	3.875	4.	4.0625	4.125
8	3	3.25	3.5	3.75	3.75	3.75	3.75
9	3	3.25	3.375	3.5	*	3.625	*
10	3	3.25	*	3.375	*	*	3.5
11	3	3.125	3.1875	3.25	*	*	3.375
12	3	3.125	*	3.25	*	*	*
13	3	3.125	*	*	3.1875	3.25	*
14	3	3.0625	*	*	*	3.125	*
15	3	3.0625	*	*	*	*	*
16	3	3.0625	*	*	*	*	*
17	3	3.0625	*	*	*	*	*
18	3	3.	3.0625	*	3.125	*	*
19	3	3.	3.0625	*	*	3.125	*
20	3	3.	3.03125	*	*	*	*
21	3	3.	*	*	3.0625	*	*
22	3	3.	*	*	*	*	*
23	3	3.	3.0625	*	*	*	*
24	3	3.	3.0312	*	*	*	*
25	3	3.	*	*	*	*	*
26	3	3.	*	*	*	*	*
27	3	3.	*	*	*	*	*

*No change observed.

The same result will also be observed in Table 5, which gives the results of the growths in a frond two and a half feet long marked down

the center with holes one inch apart. The fronds observed in this experiment show no growth beyond twenty-six inches, while in the first experiment a very slight increase was observed almost the full length of the frond.

TABLE 5. *Showing growth in each successive inch of frond 2.5 feet long.*

No.	Orig. Length	3d Day	5th Day	7th Day	8th Day
1	1	*	*	*	*
2	1	1.125	1.375	1.3125	1.375
3	1	1.125	1.375	1.5625	1.75
4	1	1.1875	1.625	1.75	2.
5	1	1.375	1.625	1.75	2.
6	1	1.1875	1.625	1.75	1.875
7	1	1.25	1.375	1.5	1.75
8	1	1.25	1.5	1.625	1.75
9	1	1.125	1.5	1.625	1.75
10	1	1.125	1.5	*	1.625
11	1	1.125	1.375	1.5	1.625
12	1	1.125	1.25	1.375	*
13	1	1.125	1.25	1.625	1.875
14	1	1.125	1.1875	1.25	*
15	1	1.0625	1.125	1.1875	1.25
16	1	1.0625	1.125	*	1.1875
17	1	1.0625	1.125	*	1.1875
18	1	1.0625	1.125	*	1.1875
19	1	1.0625	1.125	*	*
20	1	1.0625	1.125	*	*
21	1	1.0625	*	1.125	*
22	1	1.0625	*	*	*
23	1	1.0625	*	1.0833	*
24	1	1.0625	*	*	*
25	1	1.0625	*	*	*
26	1	1.0625	*	*	*
27	1	*	*	1.0625	*
28	1	*	*	*	*
29	1	*	*	*	*
30	1	*	*	*	*

*No change observed.

Since pieces three inches long cut from a frond were found to grow, experiments were attempted to find how short the pieces could be cut and still grow. Consequently pieces varying from two inches to one fourth of an inch were cut from fronds about three inches above the base, and tacked to the raft. In each piece, for the few measurements that could be taken, a slight growth was observed. This was also true of other pieces that were cut from the center of the frond; some of these were cut half an inch long and a quarter inch wide, and some a quarter inch long and half an inch wide. Tables 6 and 7 show three successive measurements of these pieces.

TABLE 6. *Showing growth in inches of small pieces of fronds with natural margins.*

Day	Length	Width	Length	Width	Length	Width	Length	Width
1st	2.	1.25	1.	1.625	.5	1.125	.25	1.25
3d	2.1875	1.25	1.125	1.75	.625	1.125	.3125	1.25
5th	2.375	1.3125	1.1875	1.875	.625	1.1875	.3125	1.3125
7th	2.3125	1.375	1.25	1.9375	.625	1.25	.375	1.375
8th	2.625	1.5	1.3125	1.9375	.75	1.25	.375	1.375

TABLE 7. *Showing growth of small pieces cut from center of frond.*

Day	Length	Width	Length	Width	Length	Width
1st	.50	.25	.25	.0	1.000	0.875
3d	.5625	.25	.30	.625	1.1875	1.000
5th	.6875	.35	.35	.625	1.50	1.0625
7th	.75	.4	.6	.6875	1.625	1.125
8th	.875	.6	.6	.6875	1.75	1.125

A rather peculiar fact observed is that the kelp fronds grow more rapidly on some days than on others. According to observations the greatest growth was on those days of most windy weather. This was probably due to the fact that the water was moved about and better aerated. According to Frye (1), Setchell (4) and Rigg (3) kelps will not grow in quiet waters, but are confined to situations where subjected to strong tidal currents.

Without the wind records during the time the observations were made on the growth of the fronds, or any knowledge of how much of this growth took place during the night when it may or may not have been windy, no definite conclusion can be drawn. However, the writer expects at a later date to collect data with regard to wind effects upon the growth of *Nereocystis*.

Different fronds grow at different rates. To show this the fronds on a plant were trimmed to a length of six inches, left to grow for a time, and again measured; it was found that they then varied from 24 to 36 inches in length. This is an extreme difference in the rate of growth in the proportion 3:5. It was usually the outer frond that grew most rapidly.

The two edges of the same frond grow at different rates. The outer margin grows most rapidly. The central region grows more slowly than the margins. These variations in the same frond account for the ruffling of the margins, and the curvature of the frond.

SUMMARY

1. Nereocystis will grow as well when loosened from its foothold on the rocks, so long as it is not carried into unfavorable situations, e. g., washed ashore.

2. The holdfast serves only to fix the plant.

3. Not only the holdfast but the stipe including the bulb are unnecessary for the growth of the fronds.

4. The fronds may be cut into very small pieces and each piece grow independently.

5.   The growing region is not at the transition place between blade and stipe.

6.   The basal limit of considerable growth is at the beginning of the flattened expanded part of the frond.

7.   The terminal limit of the growing region is difficult to fix. Growth gradually decreases toward the tips of the fronds; relatively little growth occurs beyond two feet from the bulb in an ordinary July plant.

CITATIONS

1.—1906.—Frye. T. C.   Nereocystis luetkeana.   Bot. Gaz., 42:43-146.

2.—1908.—Setchell. W. A.   Nereocystis and Pelagophycus.   Bot Gaz.. 45: 125-134.

3.—1912.—Rigg. G. B.   Ecological and Economic Notes on Puget Sound Kelps.   U. S. Senate Document No. 190, pp. 179-193.

4.—1912.—Setchell, W. A.   The Kelps of the United States and Alaska. U. S. Senate Document No. 190, pp. 130-178.

Hormiscia tetraciliata sp. nov.

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Growing abundantly in several localities in the region about the Puget Sound Marine Station there is a plant which has always been traced to the genus *Hormiscia* but whose species has not been so very certain, not fitting exactly any one of the described species (*Fig.* 1). Usually it has been referred to *H. wormskjoldii*, *H. collabens*, or *H. incrassata*. During the summer of 1914 the writers collected this species as a type for class work at the Station, and found it reproducing excellently both sexually and asexually. Careful study of the gametes showed that it did not agree in all its characteristics even with the genus *Hormiscia*. A thorough study of it was therefore made.

The holdfast is like that of *Hormiscia* (*Fig.* 3). The germinating spores begin at once to form a sheath about the filament, and when about 2 cells long the lower cell elongates pushing out 1 or 2 rhizoidlike projections. These extend downward breaking the sheath and almost always forking at least once. The lower portion of these rhizodlike projections is hyaline, not green, and the tips later are flaring so they are somewhat trumpet-shaped. Meanwhile these cells just above the lower one successively form each in the same manner one similar rhizoidlike projection. Thus the lower 6 to 15 cells form the holdfast (*Fig.* 3). The number of projections distends the sheath and more or less conceals the lower cells. The elongation of the projections pushes the plant up from the surface to which it is attached until the lower cell is lifted as much as 5 celldiameters from the substratum.

When a cell of the thread dies, leaving the upper part without a living connection with the lower part, the basal cells of the upper part form rhizoidlike projections in the normal manner. These burst through the lateral wall at the base of the lower living cell of the upper piece, and growing downward on the outside of the wall, attach themselves to the outside of the sheath of the upper cells of the lower piece. It will thus be seen that a piece cut off from a plant will become as nearly like a whole plant as the situation will permit.

Any cell above the holdfast may form an akinete. In this process the cell swells very much and absorbs the end wall below it. Not stopping

there it absorbs the cells downward consecutively, thus growing down
through the filament and eating its way as it goes (*Fig.* 5). Sometimes
it grows through a cell before absorbtion has been completed. In such
a case the unabsorbed content forms a collar about the neck of the akinete
(*Fig.* 4). The rupture or decomposition of the sheath of the thread per-
mits the akinete to escape.

The upper end of the netlike chloroplast of the akinete is dense and
has small meshes. Downward the meshes are larger, and the lower end
for $\frac{1}{4}$ to $\frac{1}{2}$ the length of an ordinary cell is quite clear (*Figs.* 4, 5).
The fingerlike strips of chloroplast extending into the clear end, so much
resemble those which extend from the lower cells into their rhizoidlike pro-
jections that it is believed the lower end of the akinete as it grows within
the old plant becomes the holdfast end of the young plant (*Figs.* 3, 4, 5).
However, this point was not determined with certainty. The upper end
of the chloroplast has all the "ear marks" of growth (*Fig.* 5), and it is
pretty certain that this is the point from which upward elongation of the
chloroplast takes place. The downward elongation of the chloroplast in
the growing akinete seems to be due to the increase in size of the meshes
of the net already formed, not to any growth of the chloroplast at the
clearer lower end (*Fig.* 5).

The gametes and zoospores were not seen in the same filament; but
any ordinary vegetative cell (*Fig.* 2) may become a zoosporeangium or a
gametangium.

In the formation of zoospores the cell contents masses around 2 to
3 dozen centers which are first recognizable by their darker color. These
then break each into a spherical or hemispherical mass of zoospores
(*Fig.* 6). The zoospores are arranged with their tails toward the center.
The mitosis resulting in such groups of zoospores would be an interesting
study.

The zoospores escape by a transverse slit in the cell wall near its
middle, and are like the zoospores in *Hormiscia* (*Figs.* 4 to 11). In
germination they draw in their cilia and tail and become more rounded.
When 2 or 3 cells are formed the lower cell distinctly shows the coming
holdfast (*Fig.* 16).

The gametes are very numerous in the gametangia. They are not
grouped within the cell as are the zoospores (*Fig.* 17). In form they
are spherical with a short papillalike snout at the base of the cilia (*Figs.*
18, 19). At the base of this snout is a red "eye spot." There are 2 con-
tractile vacuoles on opposite sides of the "eye spot." The ciliate end is
clearer. The number of cilia is 4. This seems remarkable since the

gametes in all other species of *Hormiscia* have only 2. It was at first suspected that there must be some mistake; but repeated counts in material gathered at various times showed constantly 4 cilia. Even during conjugation the 4 cilia could be seen (*Fig.* 20).

The general development and form of the plant is very closely like that of other species of *Hormiscia* with the exception of the 4-ciliate gametes. Thus it appears that this plant should be retained in the genus. It is therefore designated and described as below.

Hormiscia tetraciliata sp. nov.

Marine. Filaments simple, moniliform, cylindrical, varying in diameter from 25 μ at base to 220 μ at tip as a maximum, 6 cm. or less long, attached by the base to stones or shells or *Ulva lactuca* in the lower littoral region; holdfast a tuft of branched nonseptate rhizoidlike diverticula arising 1 or 2 from each of the lower 15 or fewer cells, descending within the sheath and projecting from its base, each branch flaring trumpetlike at its base. Cells from half to twice as long as wide, more or less barrelshaped; all cells above the holdfast region similar, capable of division and of producing zoospores or gametes; sheath in older cells as much as 15 μ thick; choroplast a rather close net, with many pyrenoids, lining the cell wall. Asexual reproduction by akinetes or by zoospores; zoospores very many in a cell, pearshaped but the narrow end tapering into a long threadlike projection, varying to more nearly spherical, tetragonal in cross section, at the large end with 4 cilia about as long as the body, without "eye spot." Gametes very many in a cell, spherical but without threadlike projection like that in the zoospores, with red "eye spot," with 4 cilia shorter than the body.

The plant differs from the genus *Hormiscia* in so far as the species have heretofore been reported, in that this plant has gametes with 4 cilia while in the others they have only 2 cilia. It thus modifies our conception of the genus. *H. tetraciliata* is nearest *H. collabens* (Ag.) Rabenh. and *H. incrassata* (Kjellm.) Collins, but has larger cells than either of them. It has been referred to *H. wormskjoldii* (Mert.) Fries, but differs from that species in having much narrower filaments. By some authors this species would undoubtedly be called *Urospora tetraciliata*.

The plant has been found at the following places, all within 10 miles of Puget Sound Marine Station: Point Caution; Goose Island, near Cattle Point; on *Ulva lactuca*, just outside Newall's Lagoon; west side of the mouth of False Bay, near Kanaka Bay; Turn Rock (Minnesota Reef); just north of Hicks Bay on Shaw Island.
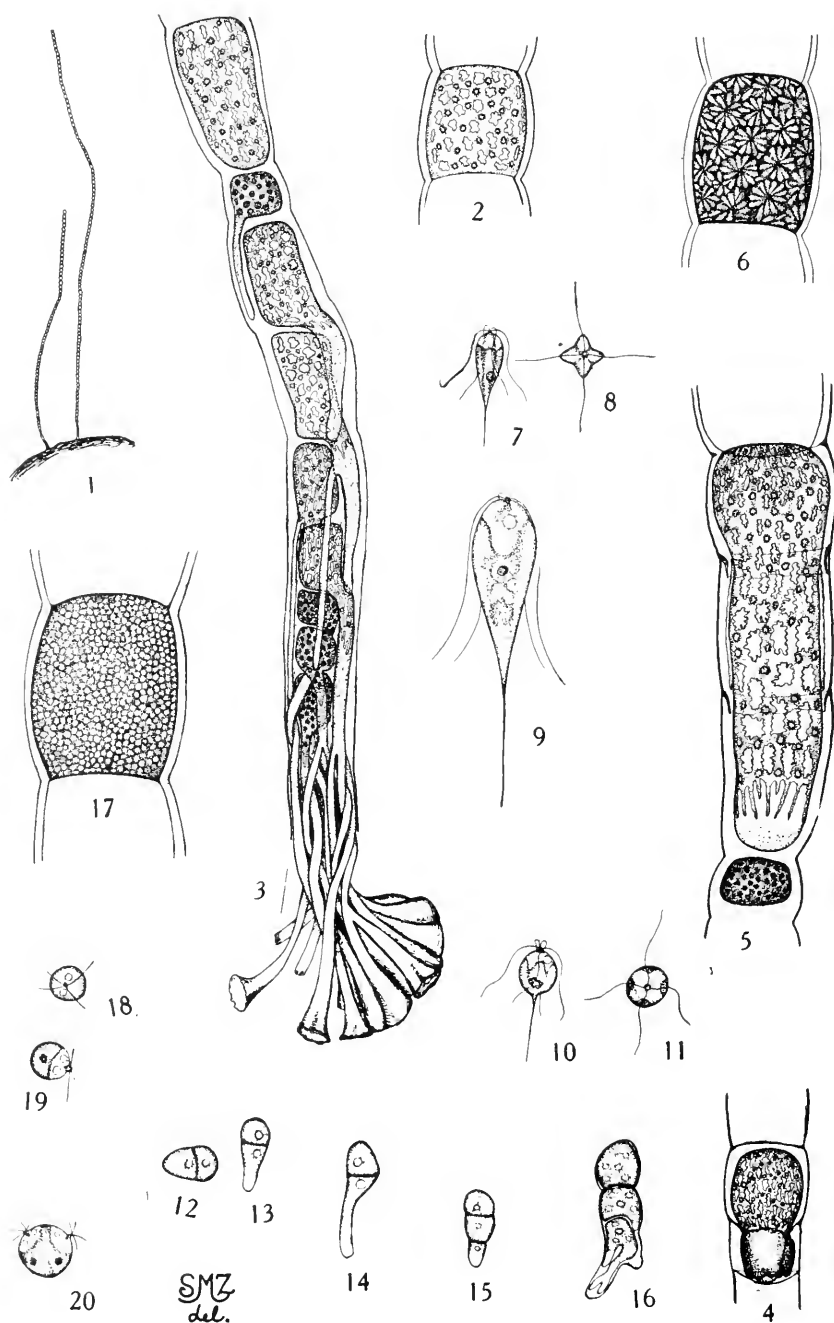
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PLATE 2

Explanation of Plate 2

1. Habit sketch. ×1.

2. Normal vegetative cell. ×75.

3. Holdfast. ×75.

4. Akinete with neck growing through a collar formed of the partially absorbed contents of the cell below. ×75.

5. A typical akinete which has grown through two cell walls. ×75.

6. A zoosporangium showing the arrangement of zoospores within. ×75.

7. Zoospore, side view. ×350.

8. Zoospore, anterior view. ×350.

9. Zoospore. ×800.

10. Zoospore rounded up, side view. ×350.

11. Zoospore rounded up, anterior view. ×350.

12—15. Germinating zoospores. ×350.

16. Germinating zoospore showing an early stage in the formation of the holdfast. ×350.

17. Gametangium. ×75.

18. Gamete, anterior view. ×350.

19. Gamete, side view. ×350.

20. Gametes fusing. ×350.

Notes on the Growth of the Stipe of Nereocystis Luetkeana

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During the summer of 1914, at the Puget Sound Marine Station, the writer attempted accurate measurements of the stipe of *Nereocystis luetkeana*. Frye, in his article on *Nereocystis luetkeana* (Bot. Gazette 42: 143-146, 1906) estimated the growth of the whole plant between the middle of March and the first of June to be about ten inches per day. This was early in the season and very possibly growth at that time was much more rapid than in July, when the laminae have been carried to the surface of the water. Frye's deductions were made from results noted by looking down through a glass bottomed bucket. He took the approximate length of the stipe of young plants in March and about seventy days later, in June, again estimated the length by general observation. From these observations he judged the average growth to be about ten inches per day.

The results given in this paper were secured by actual measurements of the stipe during the later part of June and all of July. The records showing the region of growth were made in August, since the experiments set up in July for this purpose were lost. The long, smooth stalk of the kelp is difficult to measure, since the holdfast, clinging firmly to the rocks below, keeps a great part of the plant beyond reach. At first an attempt was made to drop a weighted line down to the holdfast and then get the length by holding the plant as nearly perpendicular as possible. Now and then this succeeded, but the wind, waves and tide driving the boat about as well as disturbing the perpendicular position of the plant itself, finally made it evident that this method was of little value. Other individuals would often be found twisted about the plant in question when the second measurements were attempted; this also rendered the us of the weighted cord inaccurate.

Next the weighted cord was again taken and marked off into foot spaces. This was then attached loosely to the stipe by rings of copper wire clamped around it at intervals of about two feet. For a couple of measurements this worked well, but the wind and tide soon stirred up the kelp bed so thoroughly that the same twining of the stipes about each other

caused this method to be abandoned. The intruding kelps were usually twined so far below the surface that it was impossible to remove them.

Finally, a large number of healthy *Nereocystis* plants were pulled free from the rocks to which their holdfasts clung. Exact measurements were taken of each, from the region on the bulb where the laminae arose, to but not including the holdfast. Then these holdfasts were attached by strips of cloth either to the lower portion of a raft which was anchored at the edge of the kelp bed, or to the stipes of other individuals. Two plants were raised from the water with their holdfasts carrying the rocks to which they were attached. These, too, were measured for some time and the rate of growth was found to be approximately the same as for those torn loose, showing that anchoring the holdfasts did not affect the growth. All the plants experimented on were measured at intervals of two days, until they were broken off by wind and waves, or in some other way destroyed. Most of the measurements were made on kelps which had been anchored, since the inaccuracy in measuring fixed kelps was too great. Table 1 gives the observations on the growth of fourteen healthy specimens.

TABLE 1.   *Showing Rate of Growth of Stipes*

Original length of Stipe.	No. of days measured.	Inches of growth during entire period of measurement.	Average growth of stipe per day.
1′ 6″	6	1″	.17″
1′10″	4	2″	.50″
5′ 5″	4	1″	.25″
11′10″	2	2.5″	1.25″
13′ 6″	4	7.75″	1.94″
15′ 0″	12	5″	.42″
18′ 4″	4	1″	.25″
18′ 7″	19	49″	2.58″
20′ 7″	8	9.5″	1.19″
21′ 1/2″	8	6″	.75″
22′ 7″	4	6″	1.50″
25′ 2″	12	30.5″	2.54″
26′ 6″	20	17″	.85″
27′ 5″	20	18″	.90″

From the table one can easily figure that the average growth of the stipe per day is about 1 inch.

The number of days each plant was measured varied for several reasons: First, the kelps were often carried away by storms; second, they suffered at the hands of persons passing in small boats; third, some became entangled and were drawn too far below the surface to be freed without injury; fourth, at high tide some of the kelps would not reach the surface and thus could not be measured; fifth, decomposition often set in and destroyed them. This decomposition was often found to begin in "sunburned" spots.

The stipe of *Nereocystis* often floats out for many feet on the surface of the water and sunburn follows. One side of the large, over-wintered plant mentioned below showed this very clearly. Many other examples were found, especially after an extremely low tide. During the weeks of work in the kelp bed the writer noticed that shortly after "sunburn" took place decomposition followed. The over-wintered plants showed decomposition in practically all of the "sunburned" spots. In measuring kelps that were badly "sunburned,' in the three cases observed, no growth of the stipe was found. Just why certain kelps "sunburn" and others do not was not determined. It will thus be seen that many specimens measured for experiment were of no use. Decomposition often set in as a result of bruises caused by the plants being jammed between logs, boats, etc.

In addition to those measured in above table, one whose stipe was 47 feet 3 1/2 inches in length was also measured. This individual plant was one which had matured the year before, but survived the winter. No growth at all was found. Its holdfast had been loosened from the bottom of the sea and the plant was found floating along the edge of the kelp bed. It was covered with diatoms, *Antithamnion floccosum, Porphyra nereocystis* and other algae.

In the latter part of August a set of experiments was arranged to show the effects of mutilation, and to show the region of greatest growth. The observations on these were made by Mr. Donald Clark, a junior student in the University of Washington. These last experiments were as follows:

On August 23, two healthy kelps, the first measuring 26 ft. 5 in., and the second 28 ft. 3 in., were cut in two parts exactly 3 ft. below the base of their laminae. The openings of the hollow stipe were then corked securely. Three weeks later measurements showed a 3 in. growth from the base of the laminae to the 3 ft. cut in the shorter specimen. Decomposition had partially destroyed the remaining portion of the stipe. In the case of the longer kelp, the amount of growth in the 3 ft. piece was not enough to measure. There was also no growth in the remaining part of the stipe. Decomposition was very evident here also, but organism may not be the sole cause of death. Rigg (U. S. Senate Document No. 190; Fertilizer Resources of the U. S., pp. 185-186, 1912.) reports that experiments by Zeller show that the stipe dies when the laminae are removed. The small cut surface in that case makes death from decomposition unlikely.

A second pair were cut in the same way as the above two, but the corking of the cut region of the stipes was omitted. One of these kelp

was whipped to pieces by wave action. The second showed an inch of growth in the 3 ft. section and only one-half an inch in the remaining portion. There again what growth there was is shown to be mostly in the first three feet below the base of the laminae. As in the case of the corked specimens, decomposition was very evident, especially in the interior of the uncorked kelps.

The third experiment of this last group was of more importance. Very slight notches were cut at 2 ft. intervals, beginning at the base of the laminae and extending to the holdfasts. The results noted three weeks later are given in Table 2.

TABLE 2. *Showing the Growth in Different Parts of the Stipe, from the Laminae down*

	KELP 1			KELP 2	
	Aug. 23	Sept. 13		Aug. 23	Sept. 13
First	2′	2′ 1½″	First	2′	2′ ⅝″
Second	2′	2′ 3 ″	Second	2′	2′ 2¼″
Third	2′	2′ 2⅜″	Third	2′	2′ 3 ″
Fourth	2′	2′ 1⅝″	Fourth	2′	2′ 1⅝″
Fifth	2′ 6″	2′ 6¾″	Fifth	2′ 7½″	2′ 7¾″

From the above table it can be seen that the growing region is scattered from the bulb to the holdfast. The greatest growth by far is in the lower portion of the hollow part of the stem, while neither the bulb end nor the solid holdfast end grow rapidly.

The above results concerning the growth of kelp have all been based on plants whose laminae have reached the surface. In the spring and summer of 1915, the writer expects to work on kelps that have not as yet reached the surface and thus secure accurate data for checking the general observations made by Frye.

SUMMARY

1. The stipe grows about the same when loose as when attached.

2. The greatest region of growth of the stipe in fairly mature plants is 2 to 4 feet below the laminae, the rate decreasing toward the ends.

3. The rate of growth of the stipes measured was in July about 1 inch per day.

4. Cut stipes usually die from decomposition, apparently due to the action of organisms at the cut surface or on the interior of the hollow.

Ability of Seaweeds to Withstand Desiccation

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As one walks along a rocky seashore one cannot help observing the distribution of the seaweeds. Some species grow high up on the rocks almost near the high tide mark, others grow near the low tide, while others grow only where they are constantly submerged. It has been the writers aim to determine approximately how much desiccation some of these algae can stand and to see whether there is any relation between the ability of seaweeds to withstand desiccation and their distribution above the low tide line. The work was done between June 25 and July 27, 1914, under the direction of Dr. T. C. Frye, at the Puget Sound Marine Station at Friday Harbor, Washington.

For lack of time the work was been confined to thirteen species which are named below, under their respective groups.

    1. Chlorophyceae: *Ulva lactuca*

    2. Phaeophyceae: *Alaria valida, Nereocystis luetkeana, Desmarestia aculeata, Fucus evanescens,* and *Colpomenia sinuosa.*

    3. Rhodophyceae: *Sarcophyllis californica, Iridaea laminarioides, Gigartina, Rhodomela larix, Gloiopeltis furcata, Porphyra perforata,* and *Halosaccion glaudiforme.*

Arranging the plants in the order of their distribution on the shore-line, beginning with the forms which are highest on the rocks and going toward the low tide line, we get the following order:

1. *Gloiopeltis furcata*	8. *Iridaea laminarioides*
2. *Fucus evanescens*	9. *Ulva lactuca*
3. *Gigartina mamillosa*	10. *Sarcophyllis californica*
4. *Colpomenia sinuosa**	11. *Alaria valida*
5. *Rhodomela larix***	12. *Desmarestia aculeata**
6. *Porphyra perforata*	13. *Nereocystis luetkeana*
7. *Halosaccion glaudiforme*	

    **Colpomenia sinuosa* grew on *Rhodomela larix, Desmarestia aculeata* grew on *Nereocystis leutkeana.*

    ***Rhodomela laryx* grew in tide pools.

Of course the areas occupied by these different species overlap to some extent so that no definite dividing lines can be drawn. This is par-

ticularly true near the low tide line where a number of species seem to be struggling for the same area.

The method of procedure was to collect, desiccate, examine, and return the specimens to the water to see whether death had occured. Only good fresh specimens were taken from the water and used in the experiment. All the smaller species whenever possible were collected with their holdfasts attached to their rock substrata. A large hammer was used to chip off these rocks. The larger forms such as *Alaria* and *Nereocystis* were pulled loose with their holdfasts into a rowboat and then taken to the shore. Each specimen was labeled with a cloth tag with a number on it and was then ready to be exposed.

Only bright sunshiny days were used to dry the algae. This was done so as to reduce the variation in the time required to dry the plants to the point where they would not recover when they are returned to their natural habitat in the water. Care was taken to spread out the plants flat so that the parts of the thallus did not overlap. The specimens were exposed between 8 and 10 o'clock in the morning and were left for a definite length of time varying with the different species and individuals. One plant was never exposed alone, duplicates were always made whenever an exposure was made. The length of exposure to desiccation was determined by beginning with two extremes of exposure, and then gradually increasing the length of the minimum exposure and decreasing the length of the maximum exposure until the approximate limit of resistance to desiccation had been determined. Those plants which grow in the sublittoral zone were exposed from one to twenty-four hours and those of the littoral zone were exposed from one to ninety-six hours, the time varying with different species and individuals.

At the end of the period of desiccation the specimens were examined and then returned to the water. Those attached to rocks were placed on the bottom along the shore line where they could be easily found. The larger forms and those without rocks attached to them, were tied to a float made of a log which was tied to a rock sounded to the bottom of the sea. These specimens were then observed for a period of one to seven days, to determine whether they were able to live after a particular period of desiccation or whether it resulted in the death of the individual. The death of the algae was determined by their changes in color. The brown algae turn green when they die, except that *Fucus* turns red; the red algae turn white after death; the green algae turn white and rapidly decompose after death when returned to the water. An accurate record was kept of the time of the exposure, the condition of each individual after

exposure, and whether or not it lived when it was returned to its natural habitat.

Each species was experimented with until the approximate time of exposure which it could resist was determined. This period of exposure was worked out for thirteen species. These were then arranged in the order of their ability to withstand desiccation (*Table* 1). The last column gives the number of hours of desiccation which the species can resist, and still live when it is returned to its natural habitat. Individuals of the same species in some cases varied in their ability to resist exposure. This may be due to individual differences in the plants; but more likely to variations in the amount of humidity in the air, the temperature of the air, or the velocity of the wind.

TABLE 1.   *Showing Ability to Withstand Desiccation.*

Number	NAME OF PLANT	Number of plants used in experiment	Minimum time plants were exposed to the sun in hrs.	Maximum time plants were exposed to the sun in hrs.	Average time that the plant could resist exposure with-out resulting in death, in hrs.
1	Fucus evanescens	25	30	96	48
2	Gloiopeltis furcata	15	24	72	48
3	Gigartina mamillosa	25	24	48	24-48
4	Porphyra perforata	25	4	48	24
5	Halosaccion glandiforme	22	2	30	2- 6
6	Colpomenia sinuosa	25	2	48	2- 5
7	Rhodomela larix	16	2	20	2- 4
8	Iridaea laminarioldes	16	2	48	4
9	Ulva lactuca	17	1	30	2- 3
10	Nereocystis luetkeana	27	1	24	1-2
11	Sarcophyllis californica	25	1	6	-1
12	Desmarestia aculeata	34	1	8	-1
13	Alaria valida	15	1	5	-1
	Total	287			

The first column of Table 1 contains the names of the species used in the order of their ability to withstand desiccation. The second column gives the number of individuals experimented with of each species. The fourth and fifth columns record the minimum and maximum time during which plants were exposed to the sun. The last column gives the number of hours during which the plants could resist desiccation and still continue to live when returned to the water.

Fucus evanescens was hard to spread out evenly so that no branches of the thallus overlapped; for this reason it was often found that the entire plant did not die at the same time. It was also found that the younger plants could resist desiccation more than the older ones. In no

case did the plant recover after the mucilage in the fruiting tips was thoroughly dry.   Although the table shows that *Fucus* can resist 48 hours of desiccation, in reality it was dry only about one half that time even though it was out of water all of that time.   About one half of this time was during the night hours, when the plant often absorbs moisture from the air instead of evaporating.   This was shown by its losing brittleness and becoming rubber-like in the late afternoon or evening.

Gloiopeltis furcata seemed to be able to withstand considerable desiccation.   When dried it was at first rubber-like; later it became shriveled up, hard, and black.   When it was returned to the water after 48 hours of exposure it regained its original color and a week's observatiton showed that the plant was still growing.

Gigartina mamillosa varied considerable in its ability to withstand desiccation.   In some cases it became hard, brown and rubber-like; in other cases the specimen became very hard and dry.   Some of the specimens turned white completely while others of the same exposure turned white only at the tips and then gradually decayed when they were returned to the water.

Porphyra perforata is hard to handle because when it is dry it is like a piece of shiny rubber stretched over the rocks and breaks very easily.   The plant was spread out on a rock under water, then exposed and returned to the water with the rock.   The older plants seemed to die first in patches and around the edges, later the whole plant died.

Halosaccion glandiforme dried out easily but the length of time required depended somewhat upon the size of the sac-like thallus and the amount of water in it.   These conditions caused the period of desiccation which the plant could resist to vary from two to six hours.

Colpomenia sinuosa could withstand from two to five hours of desiccation depending upon the size of the plant and the amount of water in the hollow mass of which the plant is composed.

Rhodomela larix varied from two to four hours in the length of time it could resist drying.   The variations were probably due to the weather variations from day to day and the differences in the size of the plant.

Iridaea laminarioides can resist about four hours of drying.   When it is dry it is black and hard.   When it is exposed for desiccation for more than four hours it turns white when returned to the water.

Ulva lactuca is a very difficult species to work with on account of its size and the ease with which it breaks when it is dry.   When the plant

is dry it is dark green and brittle, but it soon looses its color and decays when it is returned to the water after more than two hours of desiccation.

Nereocystis luetkeana, the largest species experimented with, has a long stipe, holdfast, bulb, and blades. The blades are very sensitive to drying and can stand from one to two hours depending upon the size of the blade and the weather conditions. When whole plants were exposed for more than two hours they were very dry. When these were returned to the water they turned green, and soon the blades, bulb and stipe decayed.

Sarcophyllis californica can stand less than one hour of drying. Almost immediately after it is removed from the water it turns from red to a bright orange; when it is then returned to the water it looses its color and decays.

Desmarestia aculeata turns green within one hour after it is removed from the water. In no case did a plant live after it had been exposed to the sun for one hour or more.

Alaria valida is very sensitive to drying. In no case did a plant live after it had been dried for one hour. The plant dries out quickly; then when returned to the water it turns green and permanently looses its turgidity.

The observations were limited and made under somewhat variable conditions, but the general results are valuable in that they open the way for both intensive and extensive work along this line. The experiments show that some plants can live after they have been exposed to the sun for two days; others can resist exposure for only one tide; still others are practically doomed to die if they are taken from the water for an hour or less, and thus, if washed ashore and left until the tide comes in again they are sure to die.

The table shows that those plants which grow highest above the low tide line can stand the most desiccation and those species which grow at or near the low tide line can stand the least desiccation. In the distribution of seaweeds above the low tide line wave action is not as much a factor as the ability to withstand desiccation, because those plants growing at or near the low tide line are subject to the beating of the waves when the tide is low as well as those growing higher up along the shore. While it is not claimed that the ability to withstand desiccation is the only reason why some algae grow high above the low tide line the data shows conclusively that drought is one of the causes why certain seaweeds do not grow much above the low tide line.

Gas Exchange in the Pneumatocyst of Nereocystis luetkeana (Mertens) P. & R.

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and

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The chemical composition of the gas in the air chambers of certain marine algae, chiefly those belonging to the *Fucaceae* and *Laminariaceae*, has long been a question of considerable interest. As early as 1868 Rosanoff (7) had made observations on the gas evolved from certain marine algae. The gas collected from the aeriferous vesicles of *Fucus vesiculosus* consisted of pure nitrogen with no trace of oxygen or carbon dioxid.

In 1889 Willie (8) found that there is a variation in the oxygen content of the air chambers of some of the Fucaceae. In plants which were submerged at high tide he found from 35 to 37 per cent of oxygen in the day time but after being exposed to the air for 10 hours the oxygen was reduced to 20.7—20.8 per cent or practically that found in ordinary air. After remaining in the dark for 12 hours the oxygen was reduced to 2.7 per cent. Carbon dioxid was always completely lacking.

In 1911 Lucas (5) made analyses of the gases in the vesicles of *Phyllospora comosa, Hormosira banksii,* and *Cystophora monilifera.* The plants used were not the normally growing plants but were fresh-looking plants which had been cast upon shore or were floating free in the sea. His experiments showed that oxygen and nitrogen were present but he detected no carbon dioxid. Lucas outlines three possible sources of the gas: (1) atmospheric air, (2) gases produced in the metabolism of the plants themselves and (3) the gases dissolved in the sea water. Since he detected no carbon dioxid in the floats and since any process of metabolism would evolve carbon dioxide, he concludes that the gases are the result of osmosis through the plant tissues from the water. Since however his analyses for "sea water gas" show from 6 to 11 percent of carbon dioxid and since carbon dioxid diffuses and osmoses more rapidly than oxygen, and the latter more rapidly than nitrogen, we cannot conceive of the absorption of oxygen and nitrogen and the entire exclusion of carbon dioxid.

(25)

From the foregoing then it has been generally conceded, though often questioned, that the gas contained in the large air chambers of many brown seaweeds is an oxygen-nitrogen mixture. Contrary to this opinion we felt that this had not been satisfactorily determined and that the gas might be the result of the metabolic activities of the plant.

In terrestrial plants the air spaces of the leaves play a definite rôle in the ready diffusion of oxygen and carbon dioxid to and from the chlorenchymous tissues in the processes of respiration and photosynthesis. In water plants we generally find these air spaces increased in size. *Nereocystis luetkeana* (Mertens) P. & R. has a large chamber in which the evolved gases collect, and thus there is no doubt that it is due to this large pneumatocyst that the bulk of the plant is floated in the surface water so that the laminae are exposed to a maximum light. Usually buoyancy is the function attributed to these large accumulations of gas in marine algae (3, 5, 6). The cavity of the pneumatocyst is about 6 to 8 feet in length and from 1.5 to 2.0 inches in diameter below the bulb, from which it tapers to a point in the stipe. The cavity of the terminal bulb itself is generally from 4 to 5 inches in length and from 2 to 3 inches in diameter. In some specimens the bulb is no larger in diameter than that portion of the pneumatocyst just below the bulb. The capacity of an average sized pneumatocyst is approximately from 3 to 4 liters.

The work which is reported in this paper was undertaken to obtain definite data concerning the constituents of the gas content of the pneumatocyst of *Nereocystis*, with special reference to the variation in the amounts of carbon dioxid and oxygen during day and night. In this way it was hoped that we could arrive at some more definite conclusions concerning (1) the function of the pneumatocyst, (2) the source of the gases concerned and (3) the metabolic activity of marine forms which exhibit such enormous annual growth.

In 1907 Dr. T. C. Frye of the University of Washington collected the gas of *Nereocystis* with a view to having it analyzed at the department of chemistry. This, however, was not successful. During the summer of 1911 an attempt was made by one of us to analyze this gas at the Marine Station. This proved fruitless because the type of apparatus used at that time was unsatisfactory. The writers undertook the problem in the summer of 1914, using the Hempel Apparatus for Gas Analysis. The parts used consisted of the modified Wrinkler Gas Burette, a simple absorption pipette for carbon dioxid, and a double absorption pipette for oxygen (4). Alkaline pyrogallol was used as an oxygen absorbent and a solution of potassium hydroxid for the absorption of carbon dioxid. The remainder of the gas after oxygen and carbon dioxid were absorbed was not further tested, but considered as nitrogen.

The gas from the pneumatocysts was collected in jars by water displacement. The inverted jars were carefully sealed under water to prevent any mixture of air with the gas. The collections were made at 3:00 to 4:00 o'clock p. m. and 3:00 to 4:00 o'clock a. m. on different days. In this way the effects of photosynthesis and nocturnal respiration on the variation of the two gases in question could be determined. Tables I and II contain the results of the analyses for carbon dioxid and oxygen, respectively.

TABLE I.   *Showing the analyses for carbon dioxid.*

Analyses of gas collected at 3:00—4:00 a. m.			Analyses of gas collected at 3:00—4:00 p. m.		
Cubic centimeters of gas analyzed	CO_2 absorbed (in cc.)	Percent of CO_2 by volume	Cubic centimeters of gas analyzed	CO_2 absorbed (in cc.)	Percent of CO_2 by volume
49.7	1.1	2.211	55.3	0.2	0.36
66.5	1.6	2.400	57.4	0.2	0.34
52.3	1.3	2.483	48.3	0.1	0.20
64.0	1.3	2.028	57.1	0.2	0.35
35.2	0.9	2.520	54.0	0.1	0.185
56.5	1.2	2.124	61.4	0.2	0.324
52.0	1.8	3.456	...	..	...
55.6	1.4	2.506	...	..	...
57.6	1.6	2.800	...	..	...
Nocturnal average % 2.503			Diurnal average % 0.293		

Average variation of CO_2 from day to night 2.21%.

TABLE II   *Showing the analyses for oxygen.*

Analyses of gas collected at 3:00—4:00 a. m.			Analyses of gas collected at 3:00—4:00 p. m.		
Cubic centimeters of gas analyzed	Oxygen absorbed (in cc.)	Percent of oxygen by volume	Cubic centimeters of gas analyzed	Oxygen absorbed (in cc.)	Percent of oxygen by volume
57.6	5.9	10.207	61.4	7.4	12.050
64.9	7.1	10.934	63.7	7.7	12.012
51.0	5.8	11.368	57.2	7.0	12.180
62.7	6.7	10.653	48.2	6.1	12.627
39.4	4.2	10.626	65.3	8.2	12.546
63.9	7.4	11.574	70.8	8.8	12.408
54.2	5.6	10.332	. . .	. .	. . . . .
58.0	6.6	11.352	. . .	. .	. . . . .
54.0	6.0	11.111	. . .	. .	. . . . .
Nocturnal average % 10.906			Diurnal average % 12.304		

Average variation of O_2 from day to night 1.398%.

The average amount of carbon dioxid and oxygen taken together is about 13 percent of the whole gas content with a remainder of about 87 percent which we consider as nitrogen. We find here a carbon dioxid content far above that of ordinary air, varying from 10 to 100 times that of air at Kew reported by Brown and Escombe (2). The maximum amount of carbon dioxid which we obtained in any one analysis was 3.45 percent while the average amount at night proved to be 2.5 percent.

It has been found that for terrestrial green plants the amount of carbon dioxid in ordinary air is inadequate for a maximum of photosynthetic activity. Under these conditions the limited carbon dioxid pressure is one of the limiting factors in growth when the plant is strongly illuminated at favorable temperatures and with good water supply. On the other hand it has been shown by Godlewski, Kreussler, Blackman, Pantanelli and others that an increase in the amount of carbon dioxid above that ordinarily found in air increases assimilation, assuming the other factors were favorable. According to Kreussler's researches the optimal percentage seems to lie at about 10 percent while de Saussure and others have found that the growth of plants is retarded in the presence of high percentages of carbon dioxid. Blackman (1) points out that the optimum is dependent on limiting factors, especially light and temperature. Thus a tension of carbon dioxid which might give a maximum photosynthetic activity at a certain light intensity, would become a limiting factor at higher intensities.

The high percentage of carbon dioxid in *Nereocystis,* however, is not sufficient under the low light intensity and low temperatures secured in the sea water, to produce the toxic effects which some have recorded for chlorophyllous terrestrial plants. On the other hand there may be some relation between the high carbon dioxid content of the pneumatocysts of large kelps, such as *Nereocystis luetkeana* (Mertens) P. & R., *Macrocystic pirifera* (Tur.) Aghard, *Alaria fistulosa* P. & R. and *Pelagophycus porra* Setchell, and the enormous annual growth of these plants, due to an increased synthesis of carbohydrates.

The oxygen content of the pneumatocyst proves to be about one-half the percentage found in ordinary air. Our analyses in this respect agree quite consistently with those of Lucas (5) but are surprisingly lower than expected in the light of Wille's investigations. We do not attempt to explain fully this low oxygen content of the bladder. However, we know that very little is absorbed directly from the atmosphere for the pneumatocyst is immersed at high tide and only partially exposed at low tide, and according to Waynick* the amount of oxygen dissolved in sea water is very slight, 9.8 to 16.9 parts per million.

Our results show that the carbon dioxid and oxygen vary from day to night, and the range of variation is wider for carbon dioxid. As would be expected the maximum increase in oxygen occurs directly after the time of maximum photosynthetic activity, while the maximum increase in carbon dioxid is during the night. The greater range in variation of the carbon dioxide may be due to the greater solubility of the latter and thus the more rapid osmosis to and from the chamber, or it may be due to such unknown factors as the partial pressures of the gases in the mixture, or the varying pressures to which the plants are subjected with the rise and fall of tides. The variation of the two essential gases indicates that their source is to a considerable extent related to the processes of metabolism in the plants.

In conclusion we may say that our analyses indicate that the pneumatocyst of *Nereocystis* is not merely a means by which the plant is buoyed up to the light, but it serves as a reservoir in the gas exchange of the metabolic processes, and this ready supply of essential gases may have a bearing on the enormous annual growth of these plants.

*Unpublished data secured on the Expedition of the Alaska Kelp Investigation under the direction of Dr. Frank K. Cameron, Bureau of Soils, U. S. Department of Agriculture, in 1913.

For suggestions in the work reported in this paper we are indebted to Dr. T. C. Frye, of the University of Washington and Director of the Puget Sound Marine Station; and both to Dr. B. M. Duggar of the Missouri Botanical Garden and Dr. Geo. B. Rigg of the University of Washington for helpful suggestions in preparing the paper.

In the division of labor the work of writing the paper fell to Mr. Zeller, and both authors collected and determined gases.

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Experiments with Marine Algae in Fresh Water

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Among the factors affecting marine algae are heat, light, dissolved gases, evaporation, beating of waves or currents of water, the chemical composition of rocks to which they are attached and the saltiness of the water. The last factor, the relation of some marine algae to saltiness of water, was chosen for experimentation.

All parts of the sea are not equally salty, so it may be assumed that algae do not all need the same amount of salt. Algae growing near the mouths of rivers must of course be exposed to much less salt than those growing in normal sea water; and those growing in tide pools filled by spray during a season when evaporation is rapid, must be exposed to more salt than those in normal sea water; especially is this true of tide pools which are above the high-water line and often have salt crystals in them.

Osterhout[1] found that *Enteromorpha hopkirkii* would grow in distilled water for a month; and his observations on seaweeds growing on vessels plying between fresh and salt water[2] would indicate that many seaweeds would grow for a time in fresh water without injury.

It was observed that *Enteromorpha intestinalis* grows where fresh water seeps into sheltered tide pools, so it was chosen as a plant that could probably live in weak salt solutions, though it is never found growing in fresh water.

To find out the relation of *Entermorpha* to fresh water, a series of fourteen pails was placed in a fairly cool sheltered place where only the morning sun could reach them. The pails contained four liters of water each. The water was ordinary sea water diluted with the following per cents of fresh water: 100, 98, 95, 90, 85, 80, 75, 70, 60, 50, 40, 30, 20, and 10. No pail containing undiluted sea water was used, because it seemed certain that *Enteromorpha* can live in that, and the experiment was started with the single purpose of finding out if *Enteromorpha* can thrive in fresh water. For that reason the finer gradations were made near the fresh-water end of the series. Into these pails were placed stones

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[1] The Role of Osmotic Pressure in Marine Plants. Univ. Calif. Pub. Bot., 2: 229–230. 1906.

[2] The resistance of certain Marine Algae to change in Osmotic Pressure and Temperature. Univ. Calif. Pub. Bot., 2: 227–228. 1906.

upon which *Enteromorpha intestinalis* was growing. About every third day the water was siphoned off to avoid disturbing the algae and fresh water of the same per cent was added. On the days during which the water was not changed it was aerated by splashing with the hand.

At the end of five weeks all of the plants were living, but none seemed to be reproducing. The plants in the fresh-water end of the series were larger than those in the salt-water end (*Plate* 3), but they were not so deeply green. Observations on the waters in the pails showed that the water which was 100 per cent fresh became "milky" sooner than

| 100 | 98 | 95 | 90 | 85 | 80 | 75 | 70 | 60 | 50 | 40 | 30 | 20 | 10 |
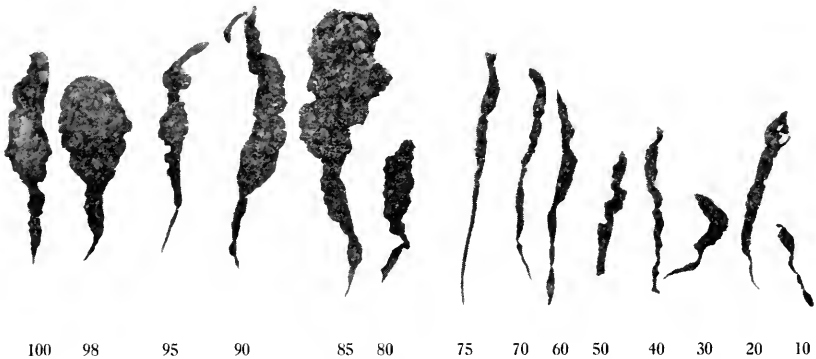
PLATE 3

A series of typical plants showing increased growth in the less salty waters. The figures below the plants indicate the per cent of fresh water in the water in which they were grown.

that in the other pails, and a slime gathered on it. It was easier to tell by feeling this water than by looking at the plants in it that it was not in so good a condition bacterially as the others. The pail and the water in it showed better the difference from the others than the algae growing in the pail. It seems probable that *Enteromorpha intestinalis* does not need salt so much for its own growth as it does to check the growth of bacteria. It would not be at all a surprise if this species would thrive in fresh water as well as in salt water if the bacterial content of the fresh water were kept down in some manner not harmful to the algae. Lack of time prevented experiments along this line.

At the end of four weeks, to get specimens to examine under the microscope, average plants that were still attached to stones were taken from each pail and laid in order. Thus was secured the series shown in Plate 3. From this series it seems that the algae grow larger in the fresher water than in the saltier water. This seems to imply that salt

water is actually harmful. It was expected that the plants would grow
in fresh water from their preference for seepages of fresh water on
the ocean beach. It was, however, unexpected that they would grow larger
in fresh water, since they are not normally found there. Livingston's
work[3] on *Stigeoclonium* indicates that strong osmotic solutions tend to
keep cells from elongating, i. e., increasing in size. Hence those in the
saltier water were likely smaller because the osmotic pressure retarded
the enlargement of the cells. However, no expriments were made look
ing toward a proof of this.

That the general effect of strong osmotic solutions is to retard
growth is known, and the literature has been summed up by Livingston.[4]
But one would naturally expect that a marine algae would grow best in
the sea.

The results also suggest that the smaller forms of *Enteromorpha
intestinalis* commonly found in salt marshes and in salt lagoons are due
to stronger osmotic solutions formed by evaporation. If this proves true
it would shed a great light on the puzzling varieties and forms of *Entero-
morpha intestinalis.*

Tests were made with other algae to see how they can endure fresh-
water solutions. Some *Fucus evanescens, Gloiopeltis furcata, Prionitis
lyallii* and *Rhodomela larix* were placed in a tub of 90 per cent sea
water. The per cent of sea water was reduced by 10 every three days.
When the solution was about 40 per cent the *Gloiopeltis* succumbed. The
other plants had a whitish coating and looked sickly, but were rather
tough in texture and withstood unfavorable conditions better than *Gloio-
peltis.* Evidently they all could not stand the change.

A tub of salt water was placed under a building where a small tap
of fresh water could run into it. Into this were placed some *Nereocystis
luetkeana, Desmarestia aculeata, Cymathaere triplicata* and *Laminaria
saccharina.* The tub was filled with salt water so that the plants would
be spared the shock of a sudden change to fresh water. On the second
day the tub was emptied so that the plants were then in a tub of run-
ning fresh water. On the third day the *Nereocystis* and *Desmarestia*
looked sickly. On the fifth day the fronds of *Nereocystis* had fallen off
and the whole plant was soft. *Desmarestia* had changed color, and *Cyma-
thaere* and *Laminaria* had begun to soften. Either these plants cannot
resist the bacteria of decay present in fresh water or they need the salts
in solution. These also therefore could not stand the fresh water.

Some *Fucus evanescens, Prioniti lyallii, Rhodomela larix* and *En-
teromorpha intestinalis* were placed in pools in a stream of fresh water.

[3]Physiological Properties of Bog Water. Bot. Gaz., 39: 348-355. 1915.
[4]The Role of Diffusion and Osmotic Pressure in Plants. Chicago, 1903.

and at the end of two weeks they were alive and seemingly healthy, but had not grown much.

These experiments indicate that *Enteromorpha intestinalis* can live and grow for five weeks in fresh water, and even thrive better than in salt water; that *Prionitis lyallii, Rhodomela larix* and *Fucus evanescens* can endure fresh water longer than can *Nereocystis, Desmarestia aculeata, Laminaria saccharina* and *Cymathaere triplicata*.

Thus algae vary greatly in their ability to live in fresh water. Just how the saltiness of the water affects the cells was not determined. It is surmised that *Enteromorpha intestinalis* would be found in fresh water were it not for the bacteria.

The Male Reproductive Organs of Some Common Crabs of Puget Sound

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During the past summer the writer, while stationed at the Puget Sound Marine Station, collected various Brachyurans for the purpose of studying their spermatogenesis. The forms which were found to be in particularly good condition during the months of June and July were the common edible crabs, *Cancer productus* and *Cancer magister;* the decorative crabs, *Hyas lyratus* and *Oregonia gracilis;* the purple shore crab, *Haemigrapsus nudus;* the helmet crab, *Telmessus chiragonus;* and the kelp crabs, *Epialtus productus* and *Pugettia gracilis.* Aside from gathering testicular material of these forms for cytological study, attention was also directed to the gross structure of the male reproductive organs, and these latter findings are set forth in this publication.

·The reproductive organs of the male crabs are located in the chamber of the cephalothorax, and when fully developed they occupy a goodly portion of this cavity. The organs lie directly below the heart and above the digestive glands, or the so-called liver. The testis (*Figs. 1-4 and 6-9, t*), which comprises the main part of the male reproductive organs, is bilobed and profusely tubular in structure. Each testicular lobe is found in the upper part of the cephalothoracic region, running laterally along the stomach. Both lobes unite in the median plane of the body, underneath the anterior portion of the heart (*Figs. 1-4 and 6-9, x*). Near this junction point two slender tubes make their origin, the so-called vasa deferentia (*Figs. 1-4 and 6-9, v. d.*), one tube originating from each testicular lobe, and these run posteriously to the base of the fifth pair of walking legs, where they open to the outside. The position, shape and size of the various male reproductive elements are shown in figures 1-9 of plates 4-6.

In *Cancer productus* the testicular lobes (*Fig 1, t*) are very well developed and occupy a larger portion of the cephalothorax than the same elements in *Cancer magister* (*Fig. 2, t*). However, in the latter the union between the lobes of the testis is developed to a greater extent than in *Cancer productus* (*compare Figs. 1 and 2, x*). The vas deferent ducts of both species (*Figs. 1 and 2, v. d.*) are coiled, straight tubes running to the base of the fifth pair of walking legs. In *Haemigrapsus*

nudus (*Fig.* 6). and in *Telmessus chiragonus* (*Fig.* 7), the lobes of the testis (*t*), their union (*x*), and the vasa deferentia (*v. d.*), conform more or less to the same plan of these elements in the edible crabs, *Cancer productus* and *Cancer magister,* as described above.

When the kelp crabs are studied, one finds that the male reproductive organs of the graceful kelp crab, *Pugettia gracilis* (*Fig.* 9), conforms to the types already described. The common kelp crab, *Epialtus productus,* however, varies somewhat from the type. Here the lobes of the testis (*Fig.* 8, *t*) are massive, and before uniting they each thin out into a very slender tubule. These tubules become united medianally (*Fig.* 8, *x*), and from their junction the vasa deferentia (*Fig.* 8, *v. d.*) make their origin.

In the decorative crabs, *Hyas lyratus* (*Fig.* 3) and *Oregonia gracilis* (*Fig.* 4), the vas deferent ducts (*Figs.* 3 and 4, *v. d.*) show interesting modifications. Here these structures are not straight tubes, but from the main ducts are given off numerous side branches in the form of blind tubules (diverticula), giving each of the vasa deferentia the appearance of a root system, the central root representing the main tube, and the rootlets representing the blindly projecting tubules. Figure 5 is an enlarged drawing of the terminal portion of one of the vas deferent ducts of *Oregonia gracilis* to show its structure. In *Hyas lyratus* the projecting tubules (diverticula) are developed to a greater degree.
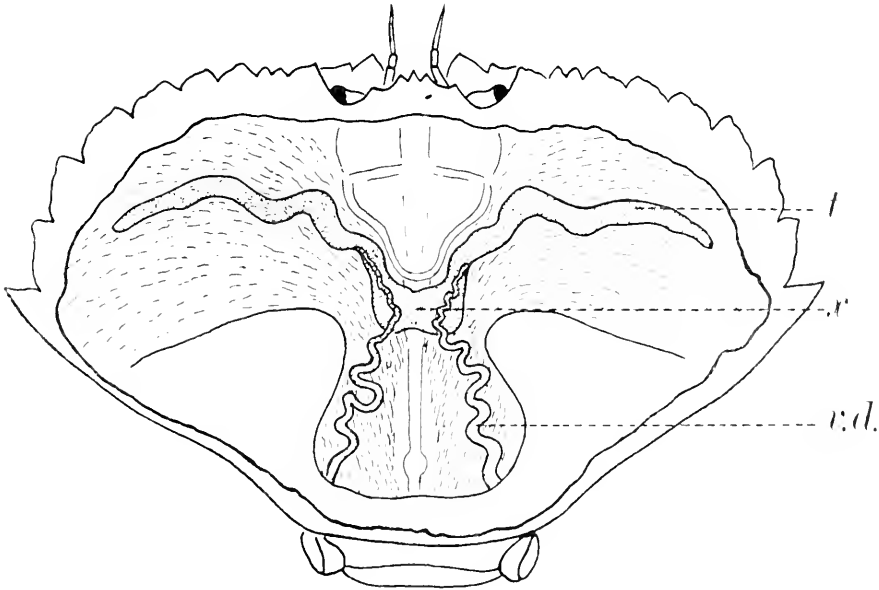
PLATE 1

Abbreviations—*t*=testis; *x*=union of two lobes of testis; *v. d.*=vasa deferentia.

Fig. 1.   *Cancer productus.*   ×1.

Fig. 2.   *Cancer magister.*   ×1.
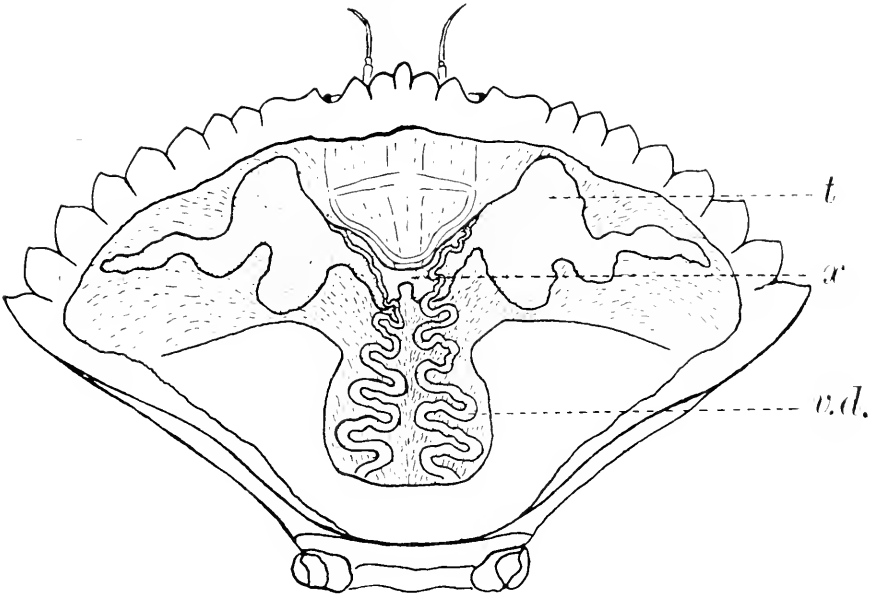
1

2

PLATE 5

Abbreviations—*t*=testis; *x*=union of two lobes of testis; *v. d.*=vasa deferentia.

Fig. 3.   *Hyas lyratus.*   ✕1.

Fig. 4.   *Oregonia gracilis.*   ✕1.

Fig. 5.   Enlarged drawing of terminal portion of vas deferent duct of *Oregonia gracilis*, showing its structure.
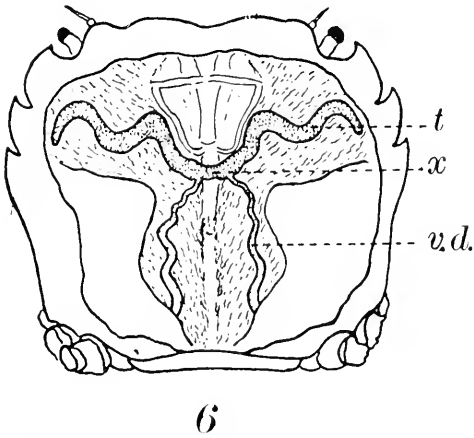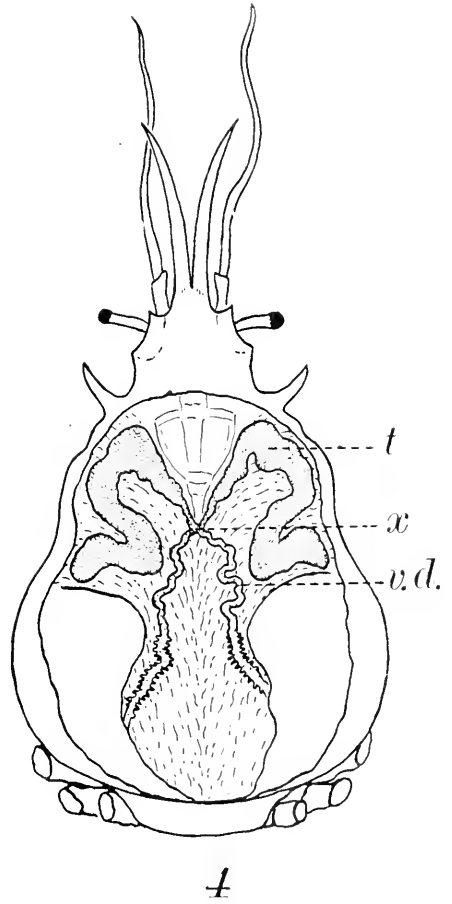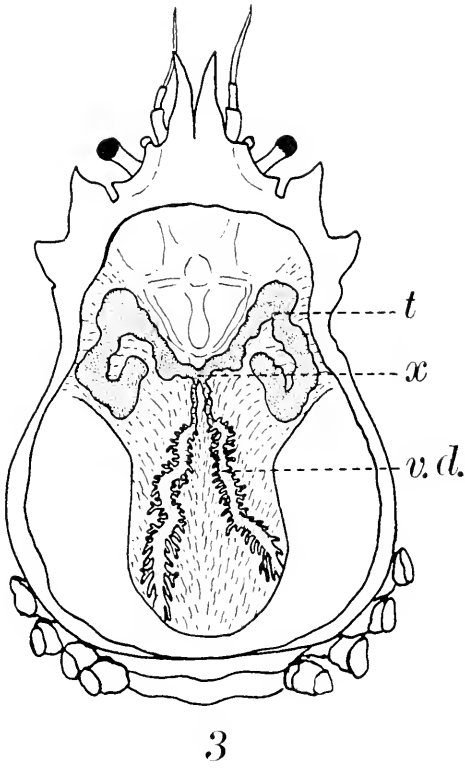
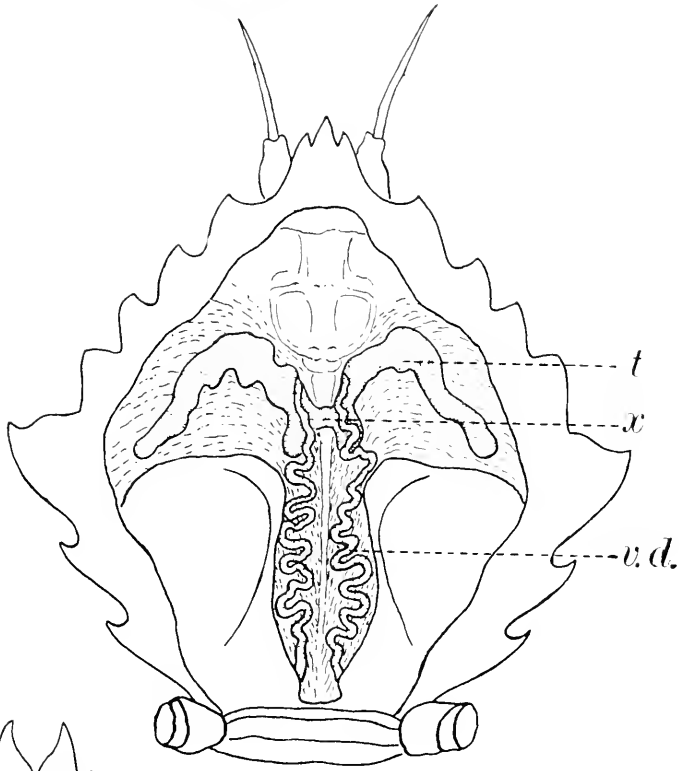Fig. 6.   *Haemigrapsus nudus.*   ✕1.

3

4

6

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PLATE 6

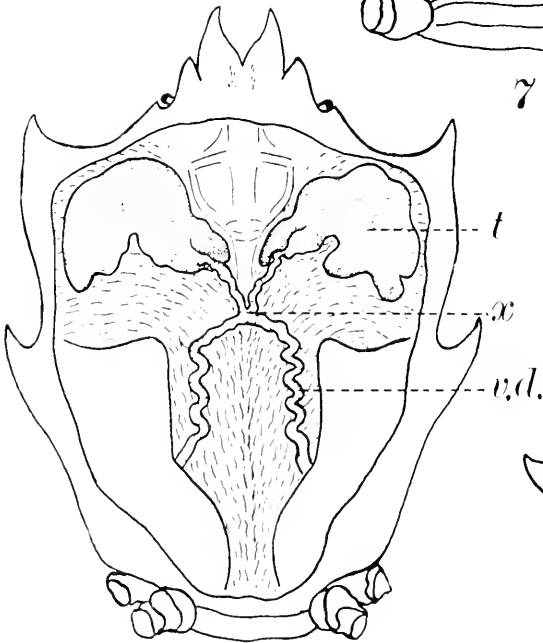Abbreviations—*t*=testis; *x*=union of two lobes of testis; *v. d.*=vasa deferentia.

Fig. 7.   *Telmessus chiragonus.*   ×1.
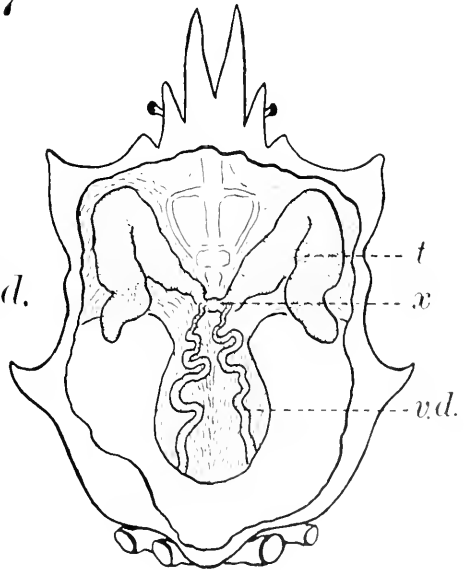
Fig. 8.   *Epialtus productus.*   ×1.

Fig. 9.   *Pugettia gracilis.*   ×1.

7

8

9

Some Points in the Structure of Alaria Fistulosa

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K. Yendo (5) reports this sub-arctic kelp as growing luxuriantly from the Kurile Islands to Shikotan Island, on the side towards the open sea. Setchell and Gardner (3) report it from the Kurile Islands to Southeast Alaska. They list none south of Wrangell Narrows. However, Dr. T. C. Frye (1) states that he observed it as far south as Augustine Bay, on Dall Island.

Setchell and Gardner (3) describe two varieties; *A. fistulosa platyphylla* as having very broad midrib and lemina, and long narrow sporophylls; *A. fistulosa stenophylla* as having a narrow midrib and lamina, and short and more or less ovate sporophylls. The material at hand varies so widely in these points that it seems probable that a careful investigation would show a gradation from one form to the other. Age seems to cause variation in these characteristics. The older ones show the *platyphylla* type, while the immature specimens generally show the *stenophylla* form of growth. Since they so closely resemble one another, all observations will apply to the general species.

The chief purpose of this paper is to trace the development of the fistulose or chambered character of the midrib (*Fig. 21*). The chambers form at an early period in the development of the plant. Setchell and Gardner (3) report distinct chambers in blades 15 cm. long. No young material was available. The region of most rapid growth is found in the base of the lamina, and since the chambers arise here, this region furnishes suitable material for investigation.

The materials used were collected by Dr. T. C. Frye and Dr. G. B. Rigg, on the United States Bureau of Soils Kelp Investigation Expedition to Alaska in 1913. The smaller specimens examined were collected by Dr. Frye at the Kashevarof Islands, southwest of Wrangell; the larger by Dr. Rigg at Anchor Point, Cook's Inlet. They were preserved in formalin. This made good sections of the larger chambers difficult to secure, as they warped considerably, even when run from formalin up through 15% alcohol. Only one entire plant was available, but there were numerous pressed and formalin specimens of type regions. Longitudinal sections of the midrib, cut perpendicular to the plane of the lamina, were found best adapted to illustrate the formation of

chambers. Type regions of the midrib were cut in cross-section also. Safranin proved to be the best general stain, but for sieve tubes and plates methylene blue was better. The best stain for sporophylls was iron alum haemotoxylin. Camera lucida drawings of typical pith regions throughout the transitional region were made. The mucilaginous matrix stained so heavily that occasionally it slightly obscured the cell arrangement.

The structure of the stipe of *A. fistulosa* so closely corresponds to that of the other Laminariaceae as reviewed by Sykes (4) that only the briefest statement regarding it is necessary. The central or medullar region includes the original pith area, and also the layers of cells added to it by the inner cortical cells. Much of the later growth results from the ingrowing of many cortical cells, forming filaments. These wander among the original pith cells, forming a complex web.

The three structural facts of prime importance from the standpoint of this paper are: (*a*) early in the life of the plant the cells of the medulla cease to divide transversely to the long axis of the plant, as is reported in *Macrocystis pyrifera* (4), *Laminaria saccharina* (4), and *Sacchoriza dermatodea* (2), while the cortical cells continue to divide transversely; (*b*) this growth of outer tissues after the inner cells cease dividing stretches the inner cells, producing a considerable degree of elongation; (*c*) the cortical cells also continue to divide radially and tangentially after the inner cells have ceased dividing.

Sykes (4) states that only in *Nereocystis* and *Macrocystis* do true sieve-tubes arise from the inner cortical cells. Methylene blue was the only special stain used to bring out the callus regions, i. e., the parts of the sieve-tubes in which cellulose undergoes hydration, preparatory to the obliteration of the sieve-tubes. Hence the investigation was not sufficient to determine with certainty whether the tubes in *A. fistulosa* were true sieve-tubes. However, these tubes so fully correspond to the sieve-tubes figured and described by Sykes (4), and so closely resemble those found in the higher plants, that there seems to be no doubt that they are true sieve-tubes.

The elongated cells of the primary pith tissue are usually peculiarly enlarged, hence they are often termed "trumpet-hyphae," although in structure they are much like the sieve-tubes formed by the inner cortical cells. Their only distinction of any consequence seems to be their difference in origin. Sykes (4) has shown in other forms of the Laminariaceae that these "trumpet-hyphae" are rightly termed sieve-tubes, hence the cells bearing sieve-plates, of both outer medulla and pith, will be referred to in this paper as sieve-tubes.

The pith area in the stipe of *A. fistulosa* runs almost wholly across

the stipe, parallel with the plane of the lamina. In the center of this area are many sieve-tubes, but towards the extremities of this area there are so many sieve-tubes that only enough space is left between them for the hyphal chains of the pith web.

The sieve-tubes of the stipe do not have greatly elongated cells (*Fig.* 1), owing to the fact that the stipe is never long. Fifteen stipes were measured, and their average length was found to be only 8.54 cm. Since it grows so little during the life of the plant, the inner cells do not need to stretch greatly because of the rapid growth of the cortical cells. The cortical cells are occasionally drawn out of proper alignment, however, thus forming clefts or rifts in the pith tissue. The upper portion of the stipe (*Fig.* 2), and the rachis (*Fig.* 3), show increasingly larger rifts, which tend to run more nearly longitudinally in the pith cylinder as the base of the lamina is approached. The rachis has longer sieve-tubes, but some of the chains of cells are found to be breaking down.

In cross-section (*Fig.* 10) these rifts run roughly parallel to the long diameter of the pith area. The size of the rifts is greater in the pith of the rachis than in that of the stipe. They are found at any point throughout the central region of the pith, and look like slits torn in the tissues by a force applied at right angles to the long diameter of the pith area. The cells lying along the sides of the pith area have become elongated in the direction of the long diameter of this area, and are very narrow. Their appearance indicates that they have been subjected to some strain in that general direction. The ragged appearance of the rifts further suggests strain.

In the lower lamina the pith is freely rifted (*Fig* 4). Patches of fairly compact hyphae lie between these rifts. The hyphal cells are larger, but no more numerous than they were in the stipe and the rachis. The central, or true pith area, broadens as the rifts in the septa increase in size.

The first true chamber in the entire plant examined was 20.6 cm. from the base of the lamina. This chamber did not arise as a new feature in the plant structure. Before its appearance, long, ragged slits appeared along the medium line of the longitudinal sections. Instead of many small rifts, there is a tendency to form one large one. A long jagged rift appears along the median line of the longitudinal section, while large masses of hyphal chains form poorly organized septa between rifts. Small clefts are found in this septum-like mass. The walls along the sides of the large longitudinal rift bulge outward slightly, as if they had by bulging torn the hyphal chains asunder, to form rifts. Only a few broken fragments of chains of sieve-tube cells now appear,

PLATE 7

Fig. 1.   Base of stipe, showing earliest rifts (R).   ×53.

Fig. 2.   Rift in upper portion of the stipe.   ×53.

Fig. 3.   Lower laminal region, showing elongating sieve-tubes and enlarging rifts.   ×53.

Fig. 4.   Last massing of hyphae before true septum is formed. Rift (R) enters from each side of hyphal mass.   ×53.

Fig. 5.   First true septum.   A few small rifts occur in it.   ×53.

Fig. 6.   *a*=Lower portion of lamina.   *b*=Sporophyll tissue being sent out from sides of rachis; irregularities of surface foreshadow division of tissues into sporophylls.   *c*=Stipe.   ×0.8.

Fig. 7.   Paraphyses forming on young sporophyll.   ×53.

Fig. 8.   Young sporophylls sent out from rachis.   ×0.4.

Fig. 9.   Mature sporangia, showing pellicle (P) in which the tips of the paraphyses rest.   ×272.

1

2

3

4

5

6

a

b

c

7

8

9
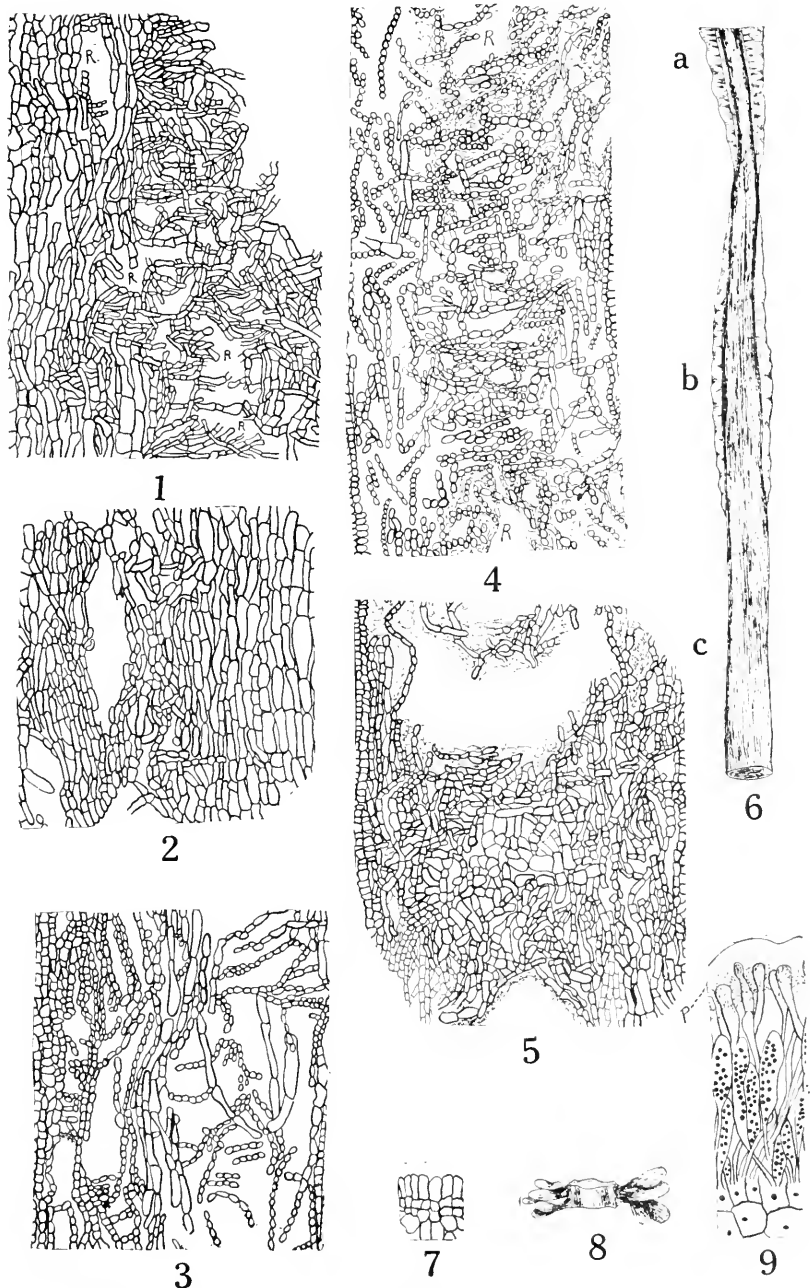
the others having broken down. The ends of the rifts are sharply angled, as if torn (*Fig.* 4). The walls of the rift are lined by many torn hyphal chains.

The first true chamber differs comparatively little from these well-formed rifts. The walls have fewer chains of hyphal cells, and the ends of the cavity are less sharply angled (*Fig.* 13). The septa are more compact, but the tissues along the sides of the chamber are rather loosely arranged, thus allowing for later enlargement of the septa as the midrib grows.

The cross-section (*Fig.* 5) now shows a solitary rift, or line of cleavage, parallel to the long diameter of the pith. The chamber thus formed has the ragged chains of hyphal cells running inward from its walls, as noted in the longitudinal section. The cells of the inner cortex show increased strain, as if being stretched by some mechanical means.

In the nearly mature septum (*Fig.* 20) the cells of the inner cortex so closely resemble those of the septum that no sharply defined line of demarcation now appears between these tissues. The walls of mature chambers are practically free from hyphae. The extremities of the chambers are no longer acutely angled, but the ends are curved outward, or may be almost flat (*Fig.* 17). The septa appear to remain about the same thickness throughout the midrib. Sloughing off of broken down cells about balances the increase in thickness as a result of cell enlargement.

In cross-section the acute angles at the extremities of the rift or chamber (*Fig.* 16) are seen to become less acute, and in the mature chamber (*Fig.* 14) the angles have disappeared, leaving the chamber oval in cross section. The tissues have been strengthened at the ends of the rift to prevent further tearing. The inner cortical cells still show the strained appearance already referred to, but the strain seems lessened.

There seems to be no definite length of chamber, but there is a gradual increase in chamber length from the base of the lamina to its widest part, though the lengths vary widely. The chambers in a single plant were measured in millimeters throughout this region, from below upward, the results being as follows: 8, 11, 9, 6, 11 25, 9, 8, 5, 13, 11, 17, 13, 19, 31, 20, 27, 17, 11, 2, 20, 23, 23, 19, 19, 38, 37, 34, 17, 42, 36, 42, 12, 47, 50, 56, 73, 69, 56, 58, 94, 56, 138, 65, 117, 113, 97, 75, 100, 83, 120, 130, 156, 103, 67, 101, 103, 128, 153, 131, 142, 181, 150, 70, 169.

The elongation of the sieve-tubes by the continued division of the cortical cells after the sieve-tube cells cease dividing, forms the basis of

this explanation of chamber formation in *I fistulosa*. Where the chains of rapidly dividing cells of the inner cortex come in contact with the now inactive sieve-tubes, the resistance to elongation offered by the passive cells naturally draws the outer cells out of proper alignment, and at the same time subjects the inactive cells to a severe strain. Hence the walls of the midrib bulge out to 'relieve the strain on the longitudinal inner cells. The bulging tears asunder the hyphal chains extending transversely across the chamber. Long continued severe strain eventually breaks the longitudinal chains of cells at their weakest points, and the tension is slightly relieved at the points between the breaks in the chains. These relaxed regions thus form the septa, the chambers representing the regions where the chains broke. Therefore, there is no definite chamber length, the length being determined by the location of these weakest regions in the cell chains. The later elongation of the chambers is due to continued transverse division and enlargement of the cortical cells.

In the cross-sectional view of the rifts and chambers a further cause of chamber formation is found. The cortical cells continue to divide radially and tangentially (4) as well as transversely, after the inner cells cease active division. The radial divisions increase the circumference of the chamber. This stretches the inactive medullar cells laterally along the sides of the medullary area. The lateral strain naturally bulges out the walls of the cortical portion, thus decreasing the strain on the inner cells parallel to the plane of the lamina. This tears the pith asunder along the median line, thus forming a chamber. This is made an easier task on account of the still greater longitudinal strain to which these tissues are being subjected. At the septa the longitudinal strain is reduced, hence the tissues are able to withstand the lateral strain as well.

As *A. valida* forms no chambers, both cross and longitudinal sections of the midrib were made for comparison with *A. fistulosa*. The pith area of the former was much smaller in cross section. If sieve-tubes had ever been produced by the inner cortex, they had all disappeared. It is probable that there had been none, since the pith region was so small it could have contained few if any. Even the primary pith cells which had been formed into sieve-tubes had broken down, leaving a rather loose pith web. The small number of either or both of these types of sieve-tubes would make it possible for them to produce a bulging of the walls to form chambers.

As already noted in *A. fistulosa*, the original pith area of the stipe had many more sieve-tubes at the ends than at the center of the pith region. In sections of the upper portion of the stipe as well as the

PLATE 8

Fig. 10.   Diagram of stipe of a two-year-old plant, showing the annual rings, and the first rifts formed.   ×3.

Fig. 11.   Diagrammatic cross section of rachis from which sporophylls are seen to be sent off; rifts are seen in the pith.   ×3.

Fig. 12.   Diagrammatic cross section of the midrib of the lower portion of the lamina; pith region shows the extremities being enlarged, foreshadowing separation from the central pith; rifts at center.   ×3.

Fig. 13.   Diagrammatic cross section of upper midrib of lamina, showing first true chamber; sieve-tube areas are definitely organized. ×3.

Fig. 14.   Diagrammatic cross section of mature midrib showing character of the chamber.   ×2.

Fig. 15.   Diagrammatic cross section of mature midrib, showing the septum.   ×2.

Fig. 16.   Acutely angled extremity of the same chamber shown in Fig. 13.   ×53.

Fig. 17.   Strengthened region at part of the chamber where an acute angle had indicated the rending of tissues along median line of pith area.   The torn hyphae along the chamber wall have almost wholly disappeared.   ×53.

Fig. 18.   Longitudinal section of mature midrib, cut perpendicular to the plane of the lamina.   ×1.5.

Fig. 19.   Longitudinal section of mature midrib, cut parallel to the plane of the lamina.   ×1.5.

Fig. 20.   Nearly mature septum; sharp line of demarcation between pith and cortex has disappeared.   ×53.

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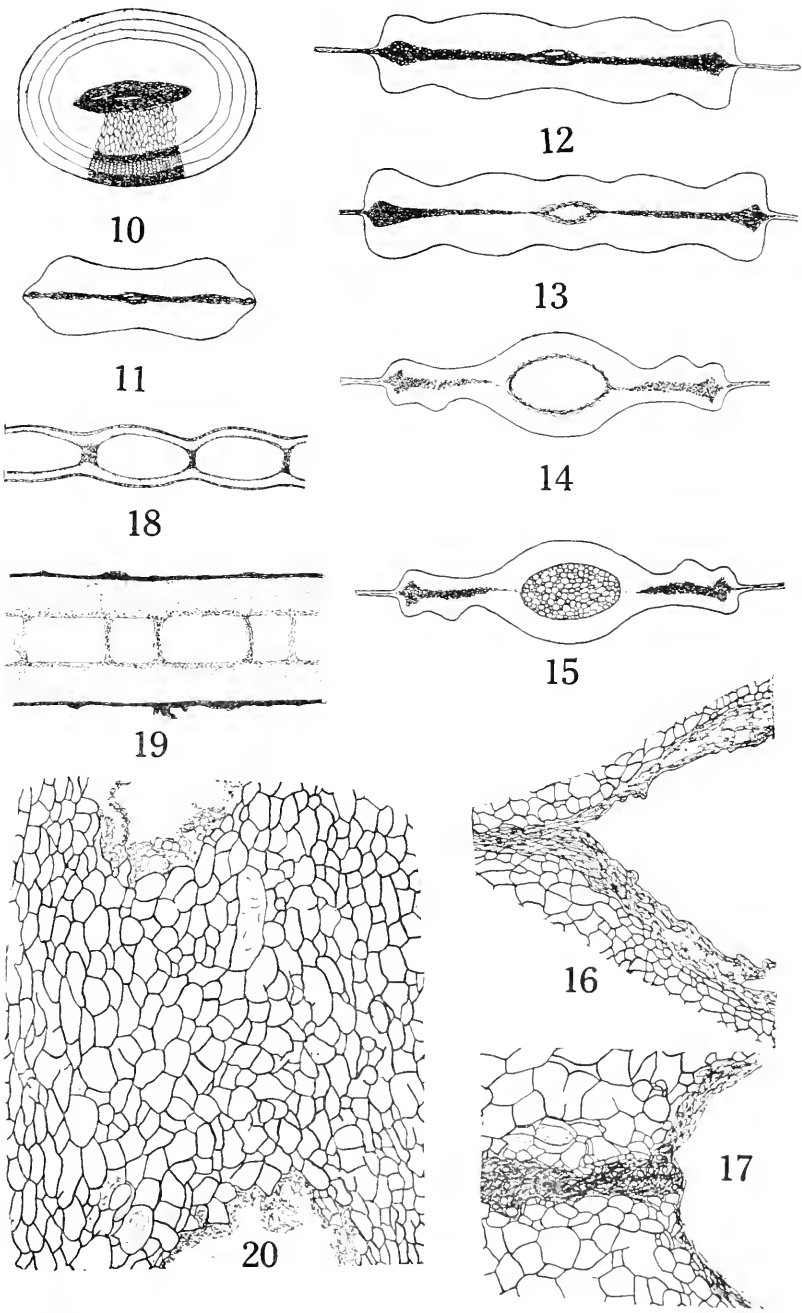
rachis and the lower portion of the midrib, these regions at the ex-tremities of the medulla were found to be gradually set off (*Figs.* 11, 12) from the central portion, or true pith, until in the midrib scarcely a trace of connection can be found between them (*Fig.* 14). In *A. valida* there is no such differentiation. The sieve-tubes in these areas are of extreme size as compared with other cells of the plant, the length being too great to measure with a micrometer eye-piece, even when a one-inch objective was used.

One is led to wonder why these cells remain unbroken while the sieve-tubes of the medullary region break down. It is probable that they are cells specialized for that particular region of the plant, as they appear to be adapted to the conditions they must meet, by their large diameter as well as their length. It may be, however, that the great number of these large tubes makes it possible for them to survive the strain. They may thus be able to retard the growth of the sur-rounding cells by holding them to a slower growth, thus preventing too rapid elongation from snapping them. Owing to the bulging of the walls of the chambers, this region of course grows slightly less rapidly than the bulged region. The relaxation of the central pith tissues by chamber formation probably slightly relieves the tension on these cells. These tubes doubtless serve as conducting channels long after the sieve-tubes of the true pith region break down.

Since the chamber in the pneumatocyst of *Nereocystis* would be likely to have a similar origin, a specimen was sectioned. Only mature specimens being available, cross-sections of the side walls of the pneu-matocysts were made. The cells lining the chamber showed signs of lateral strain, much as in mature chambers of *A. fistulosa*. MacMillan (2) shows the pith area to be surrounded by many sieve-tubes. Within he shows numerous rifts or clefts, diagrammatically. While he advances no explanation of the mechanical cause of this rifting of pith tissues, his observations almost wholly coincide with those herein recorded for *A. fistulosa*. He states that the sieve-tubes break down before the mature pneumatocyst is formed, speaks of the elongation of the cells of the inner cortex, and says that the earliest form of the pneumatocyst is elliptical, not spherical. The pneumatocyst later becomes globose, chang-ing successively to ovate and pyriform.

Considering the rifts to be caused, as in *A. fistulosa,* by the re-sistance of the many sieve-tubes to the rapid elongation of chains of the outer cells, all of these points can be easily explained. Linear strain bulges the sides; lateral strain aids in producing the globose form on account of continued radial division of the cortical cells; the sieve-tubes give way, the cortical cells continue to divide, and the resulting

linear growth causes the chamber to become successively ovate and pyri-
form. Continued growth from only one end of the rift causes it to
remain a solitary chamber. The chamber is cleared of hyphae by their
dissolution, as in *A. fistulosa.*

Another item of interest regarding the structure of *A. fistulosa*
should be noted. The cortical cells are very noticeably pitted; in many
cases the protoplasmic connections show plainly within the pits. As
noted by Sykes in *Macrocystis* (4), the pits have an appearance which
suggests puckering of the surrounding membranes. They are found
chiefly around the outer margin of the cell. The side walls of these
cells, as viewed in longitudinal section, are simliarly pitted, the num-
ber of pits averaging slightly lower. In *A. valida* these pits were
almost wholly wanting in the sections examined; only a few scattered
ones were seen.

The sporophylls of *A. fistulosa* are found along the sides of the rachis,
from 60 to 200 being produced by each plant. They arise from ridges
of tissue thrown out at the sides of the rachis (*Fig.* 6). The pith
web enters this ridge (*Fig* 11) and presents a somewhat rifted ap-
pearance. The ridge becomes more and more irregular in outline, at
last breaking up into small leaf-like bodies (*Fig* 8), into which the
pith web freely enters. The pith web is sent out from the pith area of
the medullary region of the rachis.

The young sporophylls were sectioned, and the origin of the
sporangia was traced from the formation of the paraphyses (*Fig.* 7)
to the mature stage of the sporangium (*Fig.* 9). Their development
was found to be similar to that of *Nereocystis,* as determined by Mac-
Millan (2). The epidermal cells divide transversely, the outer cells
being modified to form paraphyses. At the base of each paraphysis a
bud is sent off, which forms a sporangium. Not all sporangia arise at
one time, hence their varying sizes enable them to fit together to form
a fairly regular layer of sporangia. In mature sporophylls, raised
papillate bodies are noted on the surface. These seem to be caused
largely by an over-crowding of the surface by mature sporangia, thus
necessitating increased area. At the base of this raised portion (*Fig.*
24) the pith web thickens, evidently to strengthen the tissues to resist
strain. In some cases a rift is made by this strain, but more commonly
the cells enlarge to fill the increased space.

The sporangia are flask-shaped, and contain varying numbers of
spores. The number of spores produced by one sporophyll is extremely
large. The sporophylls on an entire plant produce so many spores that
this plant presents an extreme case of over-production, necessitated by
the great loss of spores after discharge from the sporangia. Among

PLATE 9

Fib. 21.   Portion of lamina, showing fistulose character of midrib.
×0.4.

Fig. 22.   Lower end of stipe, showing tendency to send out well-developed rhizoids from the sharply angled sides of the flattened stipe. Those on the flattened sides are poorly developed.   ×0.8.

Fig. 23.   Portion of specialized sieve-tube area, showing sieve-tubes surrounded by pith web and a mucilaginous substance.   ×272.

Fig. 24.   Cross section of sporophyll through a papillate, raised portion of the surface.   ×272.

Fig. 25.   Branched sieve-tubes, or trumpet hyphae.   ×53.

Fig. 26.   Sieve-tube from specialized sieve-tube area of the midrib.
×53.

Fig. 27.   Unbranched sieve-tubes.   ×53.

Fig. 28.   Cross section of the lamina.   ×272.

Fig. 29.   Sieve-plate from specialized sieve-tube area of the midrib.
×520.

Figs. 30-33.   Pitted cells of cortex and outer medulla of stipe. The arrows point toward the surface of the stipe.

Fig. 30.   Cortical cells near to medulla.   ×520.

Fig. 31.   Cell midway between outer and inner borders of cortex.
×520.

Fig. 32.   Cell of outer cortex.   ×520.

Fig. 33.   Cells at boundary line between cortex and medulla. The cell with a central lumen shows sieve-tube being filled with callus. ×520.

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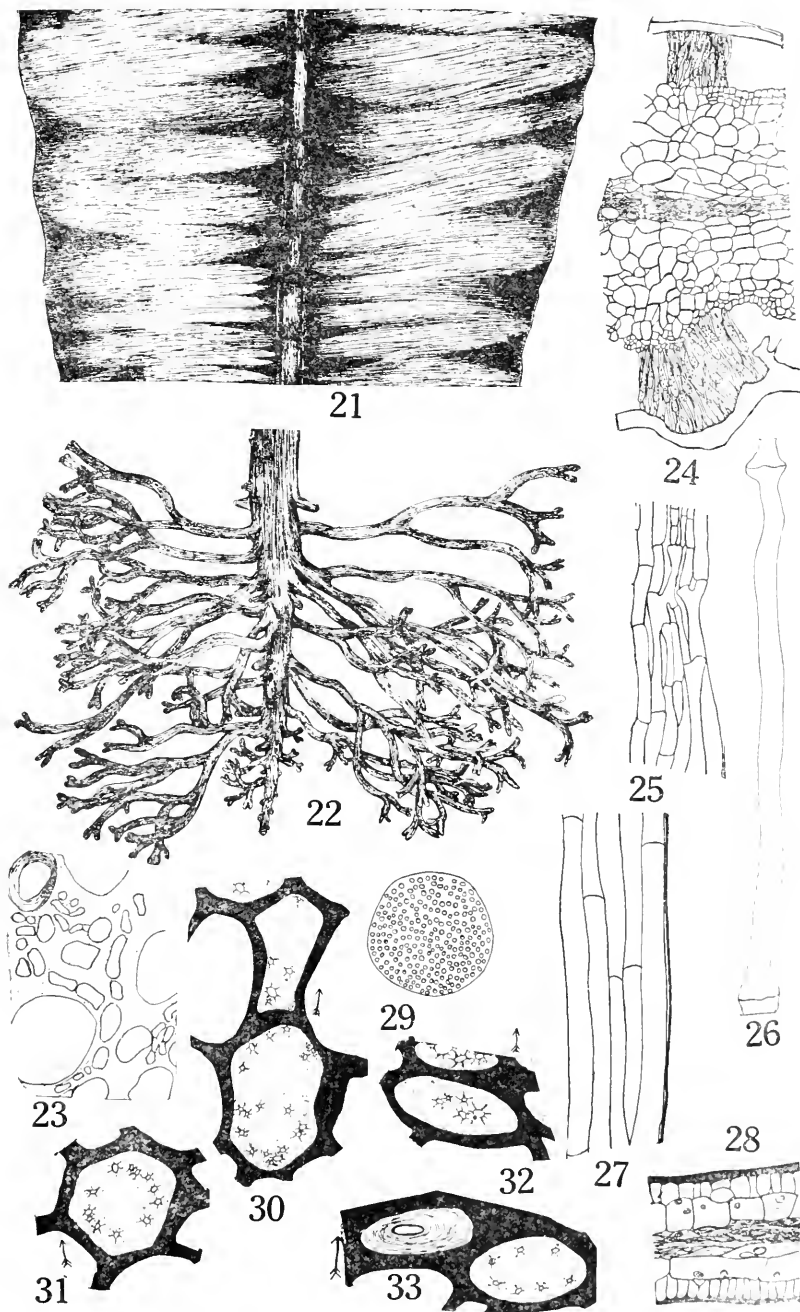
the sporangia are the longer, sterile filaments or paraphyses. These fit into a mucilaginous pellicle, which seems to serve as a protection to the young sporangia. In the mature condition this pellicle seemed to be sloughing off to permit the free discharge of spores.

The most interesting feature of the holdfasts is their tendency to send out hapteres only from the edges of the flattened stipe. Those on the flattened sides tend to remain unbranched and small (*Fig. 6*). Not all showed this so strongly as the specimen figured, but in all specimens the tendency was evident. They branch freely dichotomously, and show the structure of hapteres usual in Laminariaceae.

SUMMARY AND CONCLUSIONS

1. The chambers do not arise abruptly, but develop gradually from rifts formed in the pith tissues.

2. These rifts evidently occur as a result of combined linear and lateral strain.

3. This strain is apparently produced by the continuation of transverse and radial division of the cortical cells, after the cells of the medulla have ceased dividing.

4. A continuation of this severe strain breaks down the sieve-tubes.

5. Hyphal chains of cells torn asunder by chamber formation also soon deteriorate, losing their cellular structure. The torn chains of sieve-tubes and hyphal cells break down, forming a mucilaginous substance.

6. The continued growth of the cortical cells, after the sieve-tubes break down, causes elongation of the walls of the chambers.

7. The septa are made up chiefly of hyphal chains not broken by strain.

8. The variation in the length of the chambers is evidently due to the breaking of the sieve-tubes at the regions of greatest strain. These regions would naturally occur at unequal distances apart.

9. Specialized sieve-tube areas are developed at the extremities of the pith area. They appear to prevent undue elongation and strain from tearing down the midrib. They probably also serve as conducting vessels after the pith is broken down.

10. Normally the hapteres arise chiefly or wholly at what corresponds to the edge of the lower portion of the flattish stipe. Those arising from the flattish sides tend to remain small and unbranched.

11. The sporangia and paraphyses develop as they do in *Nereocystis*.

12. In forming sporophylls a ridge is sent out along each sharply angled side of the flattened rachis. A portion of the pith-web is sent out into each ridge. Rifts form in the pithy region. The ridge becomes irregularly and more and more deeply lobed, until the leaf-like sporophylls, each enclosing a portion of the pith-web, are formed.

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A Study of the Algal Associations of San Juan Island

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The botanists who have visited the San Juan Islands have been impressed with the large number of species and individuals of seaweeds which inhabit the rocky shores. So far little has been done on the distribution of the species of marine algae which are common on the shores of this region. Rigg (13) in his report on kelps includes a map showing the distribution of kelp beds composed of *Nereocystis* and *Macrocystis* in Puget Sound.

It is not the intention of the writer to attempt any new classification of algal zones and associations in this paper. The botanist who comes to this region for the first time is rather dismayed at the problem which confronts him—that of learning the habitats and distribution of t' many species of marine algae found here. If the discussions and charts in this brief paper regarding the algal associations of San Juan Island prove to be of any value in helping visiting botanists to get more quickly an idea of the composition and distribution of the algal flora of this island, the writer will feel amply repaid for his efforts.

The San Juan archipelago consists of over 120 islands, besides numerous rocks and reefs which are uncovered at low tide. It lies in Puget Sound in the northwestern part of the State of Washington. It is separated from the mainland on the north by Georgia Strait, and on the east by Rosario Strait. Between the southern boundary and the Olympic Peninsula lies the Strait of Juan de Fuca, while the western shores and Vancouver Island are separated by Haro Strait.

San Juan Island is located in the southwestern portion of the group. Its position is latitude 48° 30′ N., longitude 123° 5′ W. In general this island is similar to the others, but conditions for marine shore life are more varied on this than on any other single island, because its southwest coast is exposed to the tidal currents which come directly from the Pacific Ocean. The algal flora is therefore much different from that of the more protected inner shores. It is the second largest island of the group. Its greatest length from north to south is about 15 miles, while its greatest width from east to west is about 9 miles.

The shore line of San Juan Island is quite irregular. Its numerous indentations and points make it about 75 miles in length, not consider-

ing the several small islands and rocks which lie close by and are included in this study. In some places it is very rocky, while in other localities are found sandy or gravelly beaches (*Plate* 10). Most of the rocky shore is composed of metamorphic rock, which weathers very slowly and thus gives a very rough and irregular shore line. This is specially conspicuous at Point Caution, Minnesota Reef, and almost the whole of the west coast of the Island. In several places the shore is composed of limestone ledges; the largest of these are found at Limestone Point near Roche Harbor, and at several places along the west coast of the Island north of Deadman's Bay. Glacial boulders are not uncommon along the shore, specially about Kanaka Bay, at False Bay and near Cattle Point.

There are several quite large bays along the coast which have rather sandy or gravelly beaches. The largest of these are Griffin, False and Westcott Bays. One of the largest gravel beaches is along the south shore from Cattle Point westward. Here is an example of an eroding shore about 2 miles long where waves from the strait are washing into the gravel of Cattle Point Hill. There are also numerous small beaches specially in little bays and coves.

The constant motion of the tides through the channels between the islands prevents stagnation of the waters along the shore. When the tides change the water rushes very swiftly through the narrower channels and thus becomes well aerated. This is specially true of most of the points along the shore of San Juan Island. Therefore, it is not surprising to find a different algal flora at Cattle Point and Kanaka Bay from that on the quieter shores near Friday Harbor. The interval between highest flood tide and lowest ebb tide is about 4 meters, or 13 feet. This leaves some of the upper plants exposed much longer than those growing lower.

There are no large streams which enter the Sound in this vicinity, and as there are no considerable streams on the islands, the surrounding waters are free from sediment and fresh water. The absence of freshwater streams makes the salinity of the water fairly uniform about the Island. At numerous places there are small springs from which the water seeps out over the rocks along the shore and enters the salt water.

The temperature of the water is fairly uniform in the different places, and except for small tide pools, never gets very warm. The winters are too mild for the salt water to freeze, and there is no floating ice from the north to scrape the vegetation from the rocks. These factors make it possible for the more temperate algal flora of the Puget Sound region and many boreal species to find a common ground where they can intermingle.

ROCHE HARBOR

LIMESTONE POINT

WESTCOTT BAY

ROCKY BAY

MITCHELL BAY

SAN JUAN ISLAND

ANDREW BAY

POINT CAUTION

MADRONA PT

BROWN ID

FRIDAY HARBOR

MARINE STATION

TURN ID

TURN ROCK

KANSAS COVE

MINNESOTA REEF

MADRONA

LIMEKILN

DEADMAN'S BAY

PENINSULA

NORTH BAY

NEBRASKA SPRINGS

PEAR PT

GRIFFIN BAY

N

S

FILE POINT

TALBE BAY

KANAKA BAY

UTAH ROCK

ILLINOIS INLET

EAGLE POINT

CATTLE POINT

GOOSE ID

ROCKY SHORE

SANDY SHORE

LAGOON

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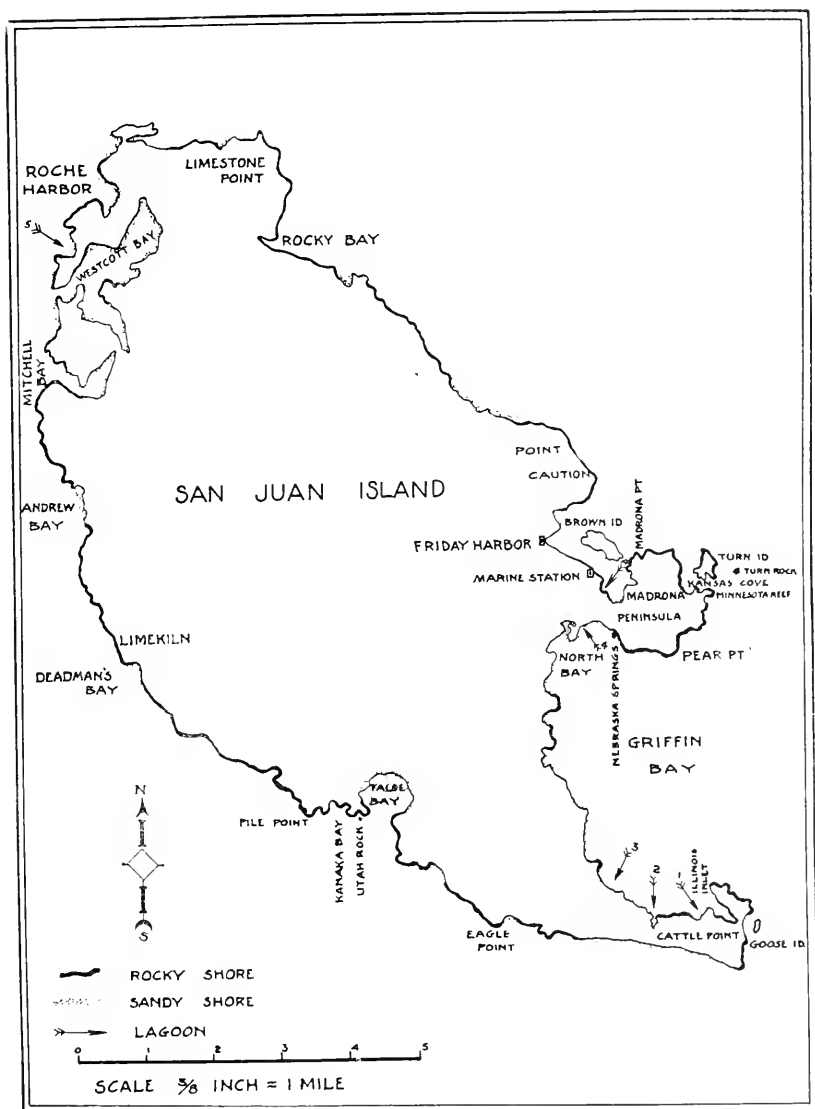
SCALE ⅝ INCH = 1 MILE

PLATE 10

Map of San Juan Island showing the indentations and the character of the shore line.

We thus find four factors which seem to be largely responsible for the abundance of the algal vegetation on San Juan Island: (a) The character of the shore line; (b) The movement of the water caused by currents and tides; (c) The absence of fresh water and debris from streams; (d) The absence of floating ice and extremes of temperature. Modifications or variations of the above factors also help to account for the distribution of the algae along the shores of San Juan Island.

In addition to these factors we must consider two others which have to do with the distribution of algae. Those species which grow above low tide must be able to withstand desiccation. The writer has shown that those algae which grow highest above the low tide line can withstand more desiccation than those which grow nearer it (11). Those plants which grow below the low tide line are growing in decreased light. Light is probably the most important factor in the distribution of algae at different depths below the water's surface.

Probably the earliest attempt to classify algal vegetation was in 1836, when J. G. Agardh (1) first recognized the three zones of algae along the coasts of Scandinavia. He named these the zone of Green Algae, the zone of Brown Algae, and the zone of Red Algae. Kjellman (9) in 1877 defined the littoral, sublittoral and elittoral zones. Later Rosenvinge (15) in 1898 modified the boundaries of these zones, and Børgeson (2) in 1905 agreed with him. According to these workers the littoral zone includes all algae which grow between the highest high tide line and the lowest low tide line. The sublittoral zone includes all algae which grow below the highest low tide line. From this it follows that between the two zones there is a band which overlaps and has algae which may belong in either littoral or sublittoral zone, as the exact line of separation is somewhat variable. This study is limited to the littoral zone and that portion of the sublittoral zone which extends down to and includes the *Nereocystis* beds.

Those areas or zones of vegetation which are dominated by one or more species are here termed "Associations." Within each association may be found one or several smaller groups which are again dominated by other than the dominant species of the association. These smaller groups are termed "Societies" by Børgeson (2), and the same term is applied to such groups here. The units of vegetation which are here called associations are larger than the 57 associations into which Davis (5) divides the algal vegetation of Woods Hole and vicinity, but the writer does not think that the five associations of algae of San Juan Island are large or distinct enough to warrant raising them to the rank of formations, nor to subdivide them into smaller associations.
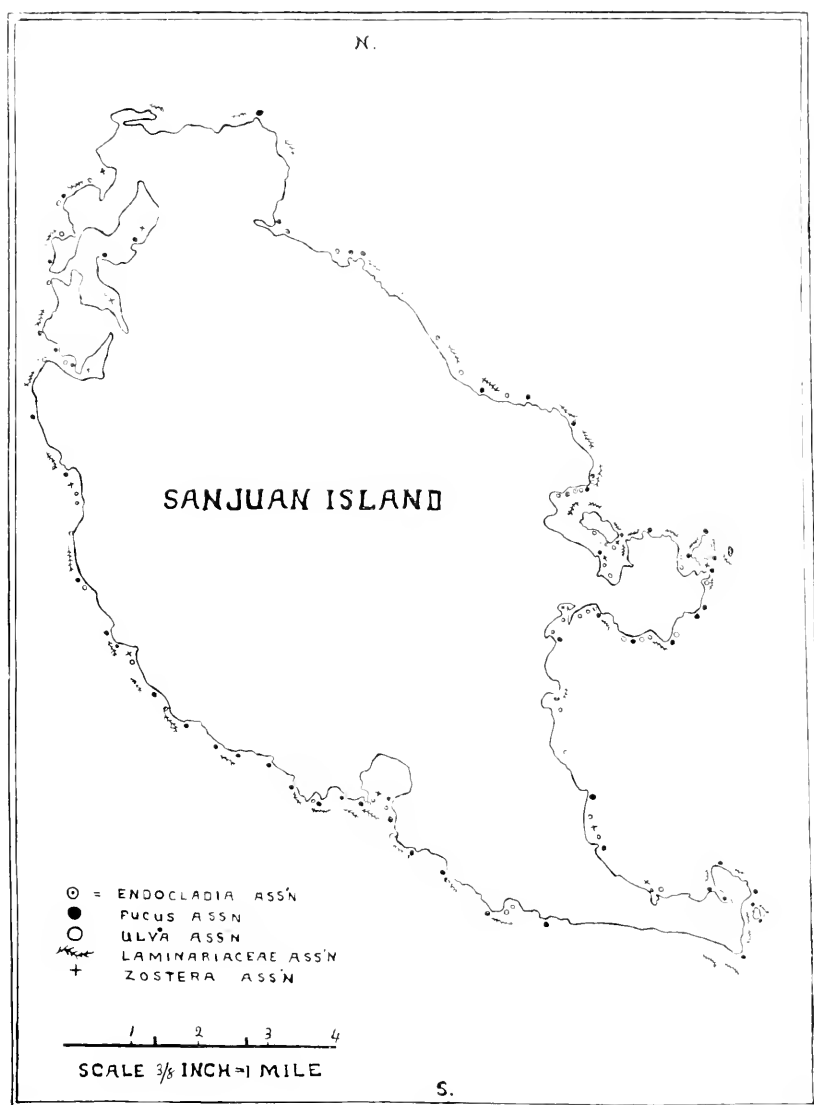
PLATE 11

Map of San Juan Island showing the distributions of the algal associations along the shore line.

The associations are named after one of the most dominant species included within them. Under each association are listed: (*a*) The *dominant* species, or those which are the most common throughout the association; (*b*) the *primary* species, or those which often form prominent societies; (*c*) the *secondary* species, or those which are found only occasionally and almost never occur in great abundance in any one place.

Between the high tide line and the low tide line, and thus in the littoral zone, we find three distinct associations extending more or less parallel with the water line, as follows:

1. *The Endocladia Association*

This association occupies the upper part of the littoral zone, forming a belt of varying width, but averaging about one meter. Where the waves dash against the rocky shore and form a spray, this association often reaches above the high tide line. In such places *Porphyra perforata* is often found. Examples of this are seen on Minnesota Reef, Cattle Point, Kanaka Bay, and along the west coast. *Endocladia muricata* is the most abundant species of this association. The plants are very small, erect and branched, and seem to be well adapted to resist the beating of the waves at high tide and the desiccating power of the sun when the tide is low.

Where fresh-water springs enter the salt water, we find *Enteromorpha linza* in great abundance. The plants are often somewhat deformed, specially those growing highest up the shore. These have been observed to grow one meter above the high water line, and there are often very pale or almost white. Within these groups of *Enteromorpha linza* one often finds *Calothrix crustacea, Anabaena variabilis* and *Cylindrospermum stagnale* growing in great abundance. The best places for collecting the above algae are near the lime kiln on the west coast of the Island and at "Nebraska Springs" (*Plate* 10).

In very rough places where tide pools are left in the pockets of the rocks, it is not uncommon to find small, much branched, yellow, almost unrecognizable specimens of *Prionitis lyallii* growing in the warm water. In the same pools one may also find small scraggly specimens of *Rhodomela larix*, specially where there is a little sand on the bottom of the pool. *Gigartina mamillosa* is also found in this association, although the individuals are much smaller and more branched than those which grow in the lower associations. Near the lower boundary are found individuals of *Gloiopeltis furcata* and *Fucus evanescens*, which really belong in the Fucus Association below.

LITTORAL ZONE

SUBLITTORAL ZONE

4 METERS

LOW TIDE LINE

LAMINARIACERE ASSN

HIGH TIDE LINE

ULVA ASSN.

TIDE POOL

FUCUS ASSN.

ENDOCLADIA ASSN.

𝖸 = NEREOCYSTIS   = COSTARIA
   = LAMINARIA   ⬭ = ULVA
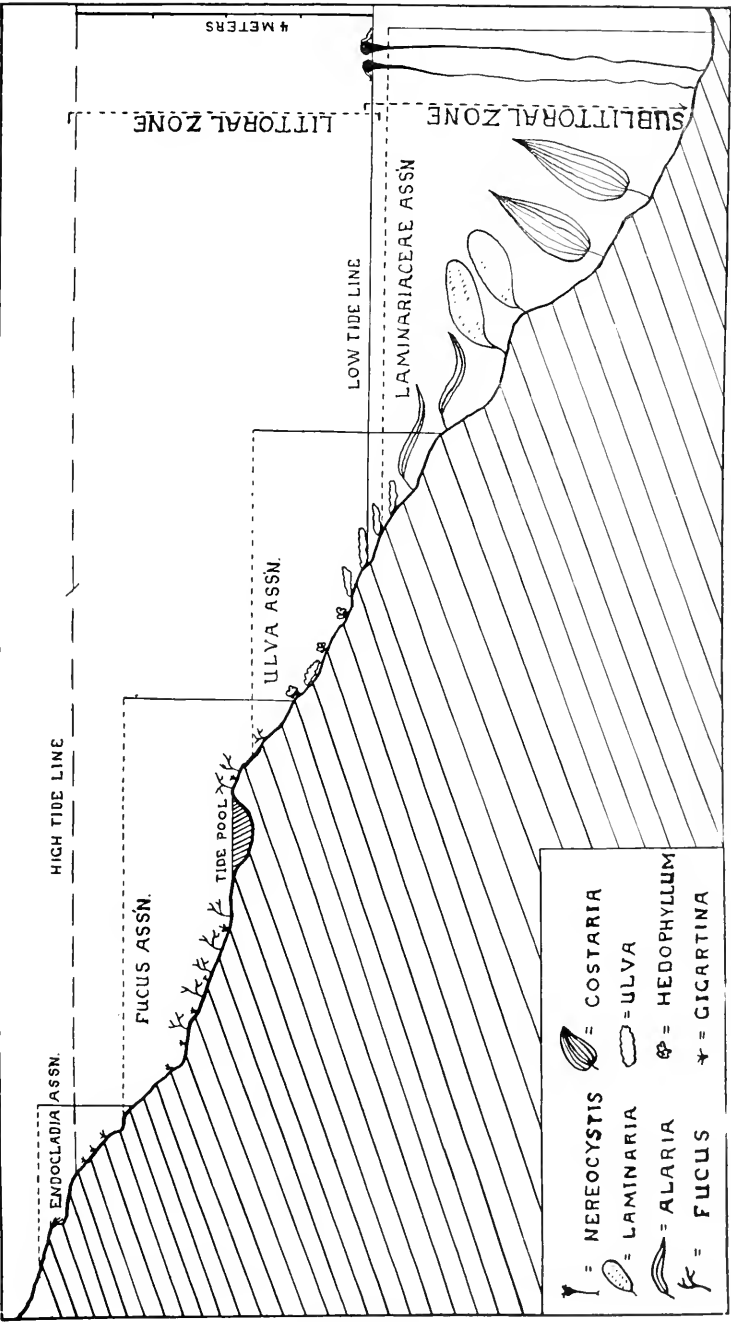   = ALARIA   ⌘ = HEDOPHYLLUM
𝖸 = FUCUS   ✶ = GIGARTINA

A diagrammatic vertical section of a rocky shore on San Juan Island showing the relative positions of the algal associations

PLATE 12

TABLE 1.   *Composition of Endocladia Association*

DOMINANT SPECIES

Endocladia muricata   Porphyra perforata

PRIMARY SPECIES

Enteromorpha linza   Gigartina mamillosa

SECONDARY SPECIES

Fucus evanescens   Gloiopeltis fureata
Prionitis lyallii*   Rhodomela larix*
Chaetomorpha sp.   Calothrix crustacea
Cylindrospermum stagnale†   Anabaena variabilis†

2.   *The Fucus Association*

The most conspicuous of the littoral associations is the Fucus Asso-
ciation of which *Fucus evanescens* and *Gigartina mamillosa* are the dom-
inant species.   This association forms a belt about two and one-half
meters high along the shore line.   *Fucus* is present on all rocky shores,
but on gravelly beaches it is replaced by *Gigartina,* which, however, is
much smaller and less abundant.   On exposed shores where the water
is very rough, such as False Bay, Kanaka Bay and Deadman's Bay,
the plant body of *Fucus* is often very different.   Here the plant has
very slender branches and the receptacles are long and narrow compared
with the broad flat branches of the plants of more quiet shores.

Porphyra perforata and *Gloiopeltis furcata* form the two most
important primary species of this association.   In tide pools *Prionitis
lyallii* occurs; and in places which remain more or less moist *Microcladia
borealis* is rather common.   Among the secondary species may be men-
tioned *Rhodomela larix* growing in tide pools with *Colpomenia sinuosa*
on it.   In a number of places *Dermocarpa fucicola* was found growing
as an epiphyte on *Fucus.*.   In some places where the water flows swiftly
over the rocks *Polysiphonia* (several species) is often found, specially
near the lower limits of this association.   In several places, as Point
Caution, Pear Point and Eagle Point, where the rocks become much heated,
Bangia atropurpurea fusco-purpurea and *Porphyra perforata* seem to
take almost complete possession.   Along the west shore and on the rocks
about Kanaka Bay, it is not uncommon to find *Hedophyllum sessile* in the
lower region with *Fucus.*

Where the rocky shore is replaced by a sandy beach *Fucus* disap-
pears.   This is true in several places along the Island, but the most

*Growing in tide pools.
†Probably fresh water forms.

prominent example of the relation of *Fucus* to its substratum is seen in False Bay. Here we find a bay with a shallow sandy bottom. When the tide goes out there is here exposed a bed of sand about three-fourths of a mile long and almost half a mile wide. This floor of sand is almost destitute of vegetation except for a few diatoms and other plants growing on the boulders strewn over the bed of the bay and on the metamorphic rocks along its southeast shore. The absence of vegetation on the floor of this bay is not due to exposure, but to the shifting nature of the sand, which makes it impossible for the algae to attach themselves permanently. The only plants which are found here are diatoms and small beds of eelgrass (*Zostera marina*), with an occasional plant of *Ulva lactuca* growing upon them. Farther out where small pebbles are present, *Laminaria bullata* and scattered plants of *Phyllitis fascia* are found. Drifted masses of *Nereocystis luetkeana*, *Cymathaere triplicata*, *Costaria costata*, *Laminaria bullata* and *Fucus evanescens* are often strewn over the bottom of the bay. The glacial boulders in the bay are covered with *Fucus evanescens*, *Gigartina mamillosa* and *Porphyra perforata*. The metamorphic rocks near the shore at low water mark have, in addition to the above species, an abundance of *Corallina officinalis* and *Hedophyllum sessile*. It is evident therefore that the kind of substratum may have a marked effect on the flora (*Plate* 13).

In the Fucus Association are found tide pools which possess a characteristic flora. These tide pools are left when the tide goes out, and thus the plants which live in them are never exposed to the drying atmosphere, but remain in the water which is heated by the sun. According to Chambers (3) the temperature of the tide pools varies from that of the sea water (11.6° C.) up to 17.2° C., an extreme difference of 5.6° C. This depends upon height above low tide, and exposure to sun, among other things. Numerous tide pools were observed and a list was made of the species which inhabited them. Table 2 shows the species which were found in each of ten typical tide pools taken from various places along the shore of San Juan Island. *Prionitis lyallii* and *Rhodomela larix* were found to be the two most abundant species in the tide pools which were studied. In table 2 the vertical columns indicate the species found in each pool. Number 1 represents the most abundant species in a given pool, while the highest number represents the least abundant species in that pool.

TABLE 2. *Showing list of algae usually found in tide pools, and their relative abundance in ten typical pools*

Names of Species	Point Caution	Madrona Point	Minnesota Reef	Madrona Peninsula	Eagle Point	Kanaka Bay	False Bay	Pile Point	Turn Rock	Deadman's Bay
Prionitis lyallii	1	2	2	1	1	2	1	1	1	1
Rhodomela larix	2	1	1	2	2	1	2	3	3	2
Colpomenia sinuosa	3	3	3	3			3	2		3
Ulva lactuca	5	4		4	4	3	4		5	
Iridaea laminarioides	6			5						
Gloiopeltis furcata	4				5					
Microcladia borealis			3		3	4	5	4	2	4
Ceratothamnion pikeanum				6					4	5

TABLE 3. *Composition of Fucus Association*

DOMINANT SPECIES

Fucus evanescens   Gigartina mamillosa

PRIMARY SPECIES

Porphyra perforata   Gloiopeltis furcata

SECONDARY SPECIES

Rhodomela larix   Colpomenia sinuosa
Prionitis lyallii   Soranthera ulvoidea
Microcladia borealis   Hedophyllum sessile
Ceratothamnion pikeanum   Dermocarpa fucicola
Polysiphonia sp.   Corallina officinalis
Ulva lactuca

3. The Ulva Association

This association occupies a vertical belt about $2\frac{1}{2}$-3 meters wide and is divided almost equally between the littoral and sublittoral zone (*Plate* 12). *Ulva lactuca,* the dominant species, cannot stand much rough water, and thus is usually found in quiet spots. Its favorite place is in bays which have shallow gravelly bottoms. The plant body is large and easily broken, and killed by exposure to the drying sun. Often after a very low tide whole beds of *Ulva* are exposed to the sun for hours; thus they are killed and dried. When the tide comes in again they rise to the surface and drift out to sea. This is the result of the plant not being able to withstand much desiccation. *Ulva* usually forms very dense beds in quiet water. In rocky places it is usually associated with other algae, among which are *Cladophora arcta* and *Enteromorpha linza.*

Where the shores are very rocky and the water is somewhat rougher, *Hedophyllum sessile* is found quite abundant in the Ulva association. Examples of this condition are seen on Turn Rock, Minnesota Reef, and along the west shore between Kanaka Bay and Roche Harbor. *Halosaccion glandiforme* usually forms rather conspicuous societies near the low tide line. *Soranthera ulvoidea* is found growing on *Odonthalia aleutica* near the low tide line in large areas and in great numbers. *Odonthalia aleutica* is also very abundant near the low tide line in regions where the water is a little rough. *Amphiroa tuberculosa* and *Corallina officinalis* are very prominent at the low tide line and just below it, on wave-beaten shores such as Kanaka Bay. In this location *Hildenbrandtia* sp. is found growing on *Phyllospadix scouleri* (*Plate* 13).

Some of the secondary species of this association often form rather distinct societies. *Codium mucronatum* is found on rocks near the low tide line on Minnesota Reef, Turn Island, Kanaka Bay, and north of Deadman's Bay. In the last named place this *Codium* was found growing on limestone ledges and on wooden piles in great abundance. *Codium*
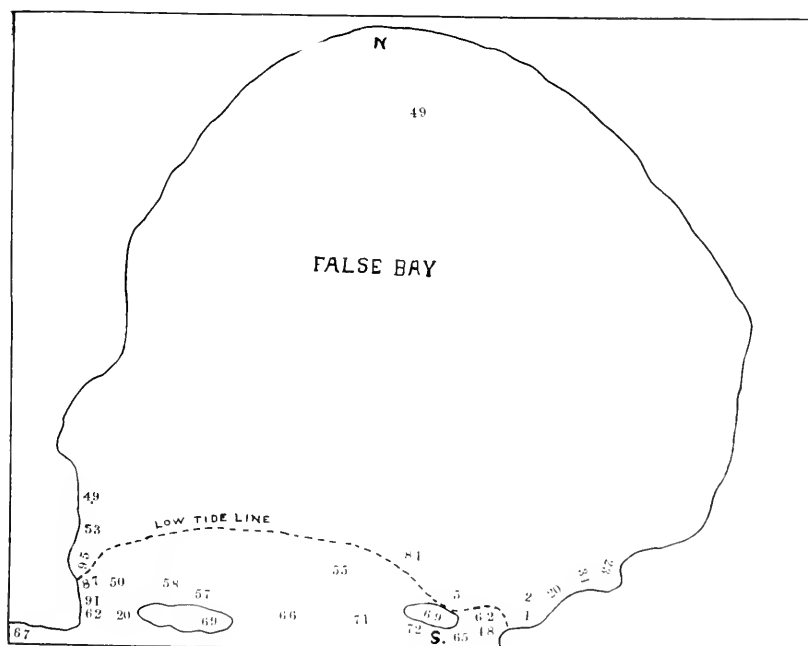
PLATE 13

Map showing the scarcity of algae on the sandy bottom of False Bay. The map covers an area roughly ½-¾ mile each way. The numbers correspond to those in the list beginning on page 76.

adhaerens grows in dense masses on perpendicular or slanting ledges just above low tide line at Point Caution, Pear Point, and Kanaka Bay.

In several places where the water washes over the rocks at very low tide, *Polysiphonia* species are very abundant. This is specially true at Turn Rock and Goose Island. *Hormiscia tetraciliata* (8) is sometimes found growing on pebbles just above low water in such quantities that the pebbles seem to be covered with a coat of green. The best examples of this condition are found in a small cove on Point Caution and at Kanaka Bay. *Cladophora scopaeformis* and *Cladophora spinescens* are also found with *Hormiscia* in several places. *Ahnfeldtia plicata* and *A. coccinna* were found on the bottom of a chasm on the shore of Goose Island near Cattle Point.

TABLE 4.   *Composition of the Ulva Association*

DOMINANT SPECIES

Ulva lactuca	Hedophyllum sessile
Cladophora areta	

PRIMARY SPECIES

Odonthalia aleutica	Halosaccion glandiforme
Soranthera ulvoidea	Enteromorpha linza
Amphiroa tuberculosa	Corallina officinalis
Polysiphonia sp.	

SECONDARY SPECIES

Gigartina redula exasperata	Monostroma fuscum
Plocamium coccineum	Codium mucronatum
Ceramium rubrum	Codium adhaerens
Cladophora scopaeformis	Hormiscia tetraciliata
Cladophora spinescens	Iridaea laminarioides
Ahnfeldtia plicata	Colpomenia sinuosa
Ahnfeldtia coccinna	Hildenbrandtia sp.

4.   *The Laminariaceae Association*

Under this group is included everything in the sublittoral zone below the Ulva association and above and including the *Nereocystis* beds. The group is named after the family which includes nearly all of the more important species, with the exception of *Cystophyllum geminatum*.

Perhaps after further study it may be possible to subdivide this association into several, but as most of the species grow below the surface of the water at low tide on rocky shores where tide currents are usually very swift, so that it is difficult to dredge the algae, it has seemed best not to subdivide this association at present. The area occupied by this association forms a broad belt of varying depth and width. The upper limit is near the lowest low tide line, and the lower limit
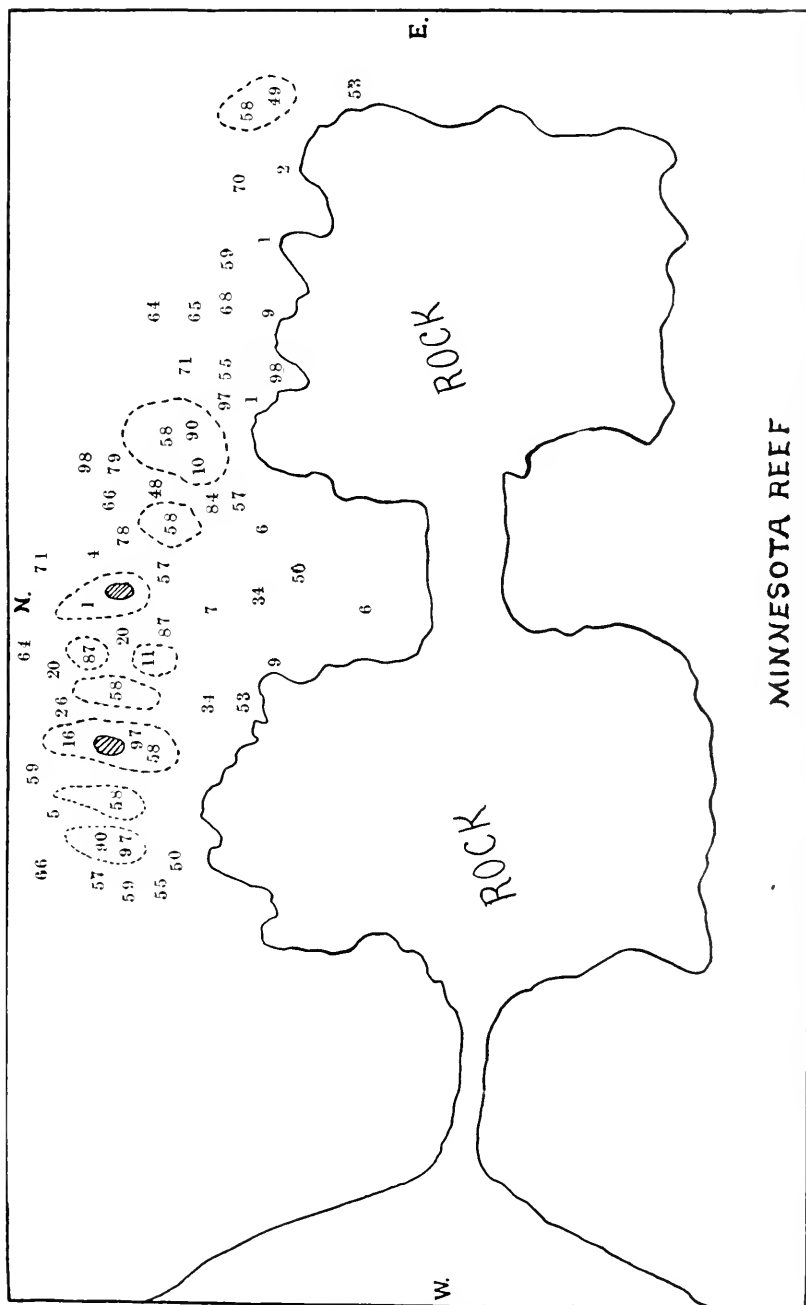
MINNESOTA REEF

Distribution of algae on Minnesota Reef. The map covers an area about $\frac{1}{4}$–$\frac{1}{8}$ miles. Dotted lines indicate rocks covered at high tide. The numbers correspond to those in the list beginning on page 76.

PLATE 14

is about twelve meters below this surface. The vertical distance can well be measured by the average length of the stipe of *Nereocystis luet-keana* minus the four meters between high and low tide. Where the shore slants gradually and the water is shallow, the *Nereocystis* beds may be several hundred meters from the shore; while in the places where the water is very deep near the shore, the beds are very narrow and quite close to the shore line.

Nereocystis luetkeana is the predominant species of this association, not only because of its large size and numbers, but because it is more easily seen than the other submerged species. *Nereocystis* is nearly always found in exposed places where the water is moving very rapidly (*Plate* 11). It must have something solid, rock or stones, for attachment. Specimens were found growing on limestone rocks near the lime kiln on the west coast where water flows over lime near the limestone quarry and then into the bay. This makes the salt water in which *Nereocystis* grows almost as white as milk. Nevertheless these plants seemed to be very large and healthy. It was noticed that the wooden piles in this vicinity are also covered with *Nereocystis, Alaria* sp. and *Costaria costata*. Evidently *Nereocystis* holdfasts may attach themselves to almost any hard substances. At Pile Point, west of Kanaka Bay, the writer had an opportunity to observe, at low tide, the vegetation growing on the wreckage of the old sailing vessel "America," which ran ashore on the rocks in September, 1914. It was interesting to note that in less than nine months after the vessel had been wrecked it was covered with full grown plants of *Nereocystis luetkeana, Costaria costata, Alaria* species, and *Laminaria bullata,* besides innumerable smaller algae of all descriptions. The kelps were attached to the woodwork, iron and copper linings of the old vessel.

Among the primary species which composed the vegetation of the Laminariaceae association, *Alaria* sp. and *Cystophyllum geminatum* grow highest or just below the Ulva association. A little further down *Laminaria bullata* is very abundant and *Costaria costata, Agarum fimbriatum* and *Cymathere triplicata* come in here, extending to and among the *Nereocystis* plants. At Pile Point, Kanaka Bay, and Eagle Point, *Egregia menziesii* grows locally abundant near the low tide line.

In the shallow quieter water *Laminaria saccharina* is often very abundant. *Iridaea laminarioides* and *Sarcophyllis californica* are found near the upper limit of this association. Near the lower limit *Rhodymenia pertusa* is sometimes dredged up, but its region of greatest abundance comes beyond the *Nereocystis* beds.

Along the rocky, wave-beaten shores *Laminaria bullata subsimplex* is fairly common and occasionally *L. andersonii* is also found. *Anti-*

thamnion floccosum, Ectocarpus siliculosus typicus and *Porphyra nereo-cystis* are frequently found on large plants of *Nereocystis*. *Enteromorpha linza* is quite common on the bulbs of old *Nereocystis* plants. *Desmarestia aculeata media* and *D. aculeata* are sometimes found on the lower portions of the stipe of *Nereocystis* and other algae. *D. ligulata herbacea* is sometimes found on pebbles and shells in the deeper beds of *Nereo-cystis,* but it grows more profusely in deeper water. *Scytosiphon lomen-tarius* has been collected on Newhall's Point and on Turn Island at very low tide. *Gigartina radula exasperata* and *Nitophyllum ruprechti-anum* may be found throughout this association, but not in very great abundance. Other species which occur in this association, but seldom in very large numbers, are listed with the secondary species.

TABLE 5. *Composition of the Laminariaceae Association*

DOMINANT SPECIES

Nereocystis luetkeana

PRIMARY SPECIES

Alaria valida	Laminaria bullata
Alaria sp.	Laminaria saccharina
Costaria costata	Cystophyllum geminatum
Agarum fimbriatum	Cymathaere triplicata

SECONDARY SPECIES

Pleurophycus garderi	Gigartina radula exasperata
Egregia menziesii	Rhodymenia pertusa
Laminaria bullata subsimplex	Nitophyllum ruprechtianum
Hedophyllum subsessile	Antithamnion floccosum pacificum
Desmarestia aculeata	Sarcophyllis californica
Desmarestia aculeata media	Ectocarpus siliculosus typicus
Desmarestia ligulata	Porphyra nereocystis
Enteromorpha linza*	Iridaea laminarioides
Scytosiphon lomentarius	Coilodesme californica

5. The Zostera Association

Besides the four algal associations which have been mentioned, eel-grass (*Zostera marina*) often forms large and dense "meadows" in quite shallow sandy bays. These plants grow in places where they are almost uncovered at low tide. Wherever *Zostera* is found, one is usually sure to find *Porphyra naiadum* growing as an epiphyte on its leaves.

In several places, near Brown Island, Westcott Bay, and near False Bay, *Zostera* plants are covered with so much *Porphyra* that the whole plants look red. The older leaves of *Zostera* are nearly always covered with filamentous diatoms. *Ulva lactuca* and *Enteromorpha linza* have

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*Rather abundant in late summer on old plants of Nereocystis leutkeana.

also been found growing on *Zostera*. *Ulva lactuca* sometimes grows quite abundantly among *Zostera* plants. *Agardhiella tenera* and *Polysiphonia* species are sometimes found growing on pebbles and shells. This includes all the common plants of this association with the exception of those forms which occasionally drift into the eelgrass.

Table 6.   *Composition of the Zostera Association*

DOMINANT SPECIES

Zostera marina

PRIMARY SPECIES

Porphyra naiadum   Diatoms

SECONDARY SPECIES

Enteromorpha linza	Agardhiella tenera
Polysiphonia sp.	Ulva lactuca

One of the best places to observe the abundance of the algae is on Minnesota Reef, on the eastern extremity of Madrona Peninsula. Here we find represented each of the several associations. The reef is only a few hundred yards long and much less wide, but it presents a variety of conditions and habitats so that many species are found here. The number of species on this reef is so numerous that it has become a favorite collecting place for students of algae. On a single day at low tide the writer has observed 48 species of algae growing on and in the immediate vicinity. Plate 14 shows the distribution of algae on Minnesota Reef.

The following is a list of the algae found on Minnesota Reef and immediate vicinity:

RHODOPHYCEAE

1.† Corallina officinalis*	23. Rhodomela larix
2. Amphiroa tuberculosa	26. Polysiphonia sp.*
4. Constantinea rosa-marina	27. Polysiphonia sp.
5. Sarcophyllus californica*	32. Nitophyllum ruprechtianum
6. Prionitis lyallii*	34. Halosaccion glandiforme*
7. Grateloupia cutleriae	35. Plocamnion coccineum
9. Gloiopeltis furcata*	42. Agardhiella tenera
10. Microcladia borealis	45. Callophyllis flabellulata
11. Ceramium codicola*	48. Gigartina radula exasperata
16. Ceratothamnion pikeanum laxum	49. Gigartina mamillosa*
	50. Iridaea laminarioides*
18. Dasyopsis plumosa	52. Endocladia muricata*
20. Odonthalia aleutica*	53. Porphyra perforata*
22. Odonthalia floccosa	55. Porphyra naiadum

†The number preceding each name refers to the number by which it is indicated on the chart.
   *Those species which are very abundant on this reef.

PHAEOPHYCEAE

57.	Cystophyllum geminatum*	71.	Laminaria bullata*
58.	Fucus evanescens*	72.	Laminaria saccharina
59.	Alaria sp.*	76.	Leathesia difformis
64.	Nereocystis luetkeana*	78.	Desmarestia ligulata herbacea*
65.	Agarum fimbriatum*	79.	Desmarestia aculeata
66.	Costaria costata*	80.	Soranthera ulvoidea
68.	Cymathaere triplicata	83.	Colpomenia sinuosa
69.	Hedophyllum sessile	84.	Coilodesme californica*
70.	Hedophyllum subsessile*		

CHLOROPHYCEAE

87.	Codium mucronatum*	97.	Ulva lactuca*
90.	Cladophora arcta*	98.	Entermorpha linza*

Vegetation in Lagoons

Along the shores of San Juan Island there are a number of small lagoons. The conditions for plant life in these lagoons are much different from those along the shore line, so that they possess a somewhat characteristic vegetation. A number of these lagoons were examined, and, as previously observed by Chambers (3), the water becomes quite warm when the tide goes out. These pools are connected with the main body of water by a tide stream through which the water runs in and out, depending upon the direction of the tide (*Plate* 15). The vegetation of the warm pools of the lagoons is very different from the vegetation of the swift-running tide streams connecting them with the main body of water (*Table* 15).

The distribution of species in a typical lagoon is shown in Plate 15.

TABLE 7. *Showing the species of algae growing in lagoons; * indicates presence*

Name and Location of Lagoon	Prionitis lyallii	Polysiphonia sp.	Iridaea laminarioides	Ulva lactuca	Laminaria bullata	Enteromorpha intestinalis	Ceramium rubrum	Diatom	Enteromorpha clathrata	Enteromorpha linza
Argyle (Plates 10 and 15)—										
Tide stream	*	*	*	*	*	*				*
Pool			*			*	*	*		
Newhall—										
Tide stream										
Pool				*			*	*		
Cattle Point 1 (Plate 10)—										
Stream	*	*				*			*	
Pool	*	*	*	*		*			*	
Cattle Point 2 (Plate 10)—										
Stream	*	*	*	*		*			*	
Pool			*					*	*	
Cattle Point 3 (Plate 10)—										
Stream	*	*		*		*	*			
Pool				*				*	*	
False Bay—										
No stream										
Pool				*		*		*	*	
Roche Harbor (Plate 10)—										
Stream	*			*						
Pool								*	*	

Prionitis lyallii, Iridaea laminarioides and *Enteromorpha intestinalis* are the most abundant forms in the tide streams. *Entermorpha clathrata, Ceramium rubrum* and diatoms are found in the pool of almost every lagoon. *Laminaria bullata* and *Polysiphonia* were especially common in the tide stream of Argle lagoon.

List of Marine Algae Found on San Juan Island

RHODOPHCEAE   *

1. Corallina officinalis L.   lli, a
2. Amphiroa tuberculosa (P. and R.) Endl.   sli, a
3. Schizymenia coccinea Harvey   sli, vr
4. Constantinea rosa-marina (Gmelin) P. and R.   lli, r
5. Sarcophyllis californica J. Agardh   sli, c
6. Prionitis lyallii Harvey   li, a

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*uli=upper littoral; l=littoral; lli=lower littoral; sli=sub-littoral; va=very abundant; a=abundant; c=common; r=rare; vr=very rare; d=drifted ashore.
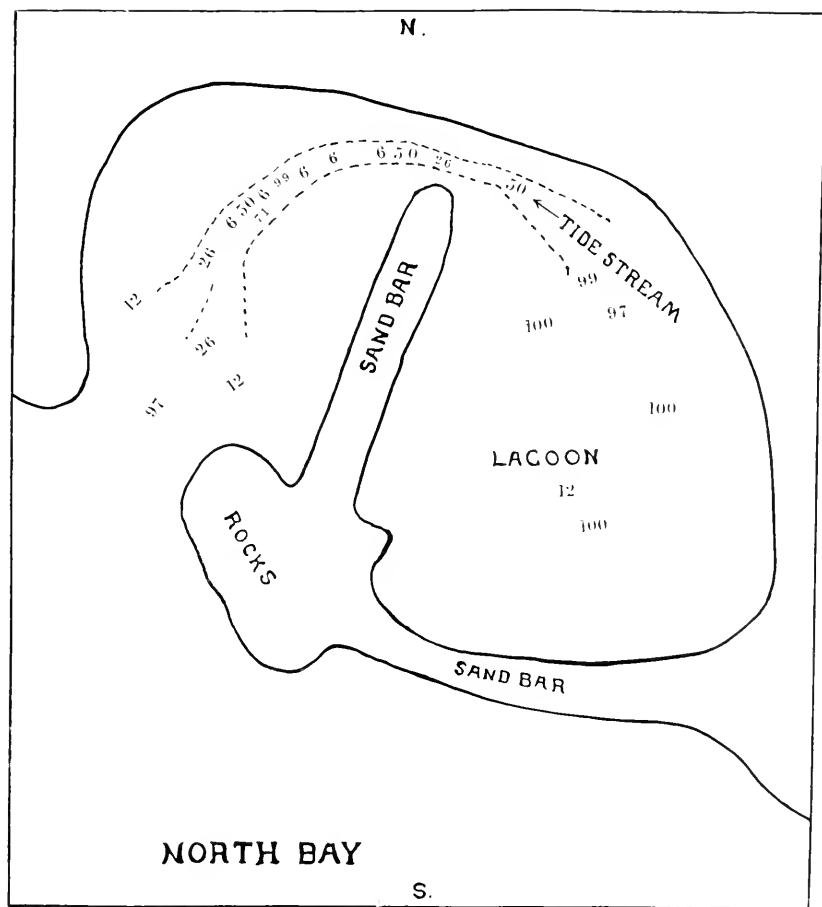
N.

TIDE STREAM

SAND BAR

LAGOON

ROCKS

12

97

26

6 50 6 99 6

6 50 26

50

99

97

100

100

12

100

SAND BAR

NORTH BAY

S.

PLATE 15

Map showing the distribution of algae in Argyle Lagoon. The map covers an area of about ¼ square mile. The numbers correspond to those in the list beginning on page 76.

7.	Grateloupia cutleriae (Binder) J. Agardh	lli, r
8.	Aeodes nitidissima J. Agardh	sli, vr
9.	Gloiopeltis furcata (P. and R.) J. Agardh	uli, va
10.	Microcladia borealis Ruprecht	li, c
11.	Ceramium codicola J. Agardh	lli, c
12.	Ceramium rubrum (Hudson) Agardh	sli, r
13.	Ceramium californicum J. Agardh	sli, r
14.	Platythamnion heteromorphum typicum Setchell and Gardner	sli. r
15.	Antithamnion floccosum pacificum (Harvey) Setchell and Gardner	sli, c
16.	Ceratothamnion pikeanum laxum Setchell and Gardner	sli, c
17.	Griffithsia sp.	lli, vr
18.	Dasyopsis plumosa (Harvey and Bailey) Schmitz	sli, c
19.	Odonthalia semicostata (Mertens) J. Agardh	lli, r
20.	Odonthalia aleutica (Agardh) J. Agardh	lli, va
21.	Odonthalia lyallii (Harvey) J. Agardh	lli, r
22.	Odonthalia floccosa (Esper) Falkenberg	lli. r
23.	Rhodomela larix (Turner) Agardh	li, c
24.	Pterosiphonia dendroidea (Montagne) Falkenberg	sli, c
25.	Pterosiphonia arctica (J. Agardh) Setchell and Gardner	sli, r
26.	Polysiphonia (1)	li, a
27.	Polysiphonia (2)	lli. c
28.	Polysiphona (3)	lli, r
29.	Laurencia pinnatifida (Gmelin) Lamouroux	lli, r
30.	Bonnemaisonia hamifera Hariot	sli, r
31.	Apoglossum decipiens J. Agardh	sli, vr
32.	Nitophyllum ruprechtianum J Agardh	sli, c
33.	Nitophyllum latissimum (Harvey) J Agardh	sli, c
34.	Halosaccion glandiforme (Gmelin) Ruprecht	lli, c
35.	Plocamium coccineum (Hudson) Lyngbye	lli, c
36.	Rhodymenia pertusa (P. and R.) J. Agardh	sli. a
37.	Fauchea gardneri Setchell	sli
38.	Fauchea fryeana Setchell	sli, vr
39.	Gracilaria confervoides (L.) Greville	sli, vr
40.	Euthora fruticulosa (Ruprecht) J. Agardh	sli, r
41.	Anatheca furcata Setchell and Gardner	sli, r
42.	Agardhiella tenera (J. Agardh) Schmitz	sli, a
43.	Callymenia phyllophora J Agardh	sli, r
44.	Callophyllis furcata dissecta Farlow	sli. r
45.	Callophyllis flabellulata Harvey	sli. c
46.	Ahnfeldtia concinna J. Agardh	lli. vr
47.	Ahnfeldtia plicata (Hudson) Fries	lli, vr

48. Gigartina radula exasperata (Harvey and Bailey) Setchell   sli, c
49. Gigartina mamillosa (Goodenough and Woodward) J. Agardh uli. va
50. Iridaea laminarioides Bory   sli, c
51. Rhodoglossum latissimum J. Agardh   sli, vr
52. Endocladia muricata (Harvey) J. Agardh   uli. va
53. Porphyra perforata J. Agardh   uli, va
54. Porphyra nereocystis C. L. Anderson   sli. r
55. Porphyra naiadum C. L. Anderson   sli, va
56. Hildenbrandtia sp.

PHAEOPHYCEAE

57. Cystophyllum geminatum (Agardh) J. Agardh   sli, a
58. Fucus evanescens Agardh   li, va
59. Alaria valida Kjellman and Setchell   sli, a
60. Alaria sp.   sli, c
61. Pterygophora californica Ruprecht*   d
62. Egregia menziesii (Turner) Areschoug   lli, r
63. Macrocystis pyrifera (Turner) Agardh*   d
64. Nereocystie luetkeana (Mertens) P. and R.   sli. va
65. Agarum fimbriatum Harvey   sli, a
66. Costaria costata (Turner) Saunders   sli, va
67. Pleurophycus gardneri Setchell and Saunders   sli. r
68. Cymathaere triplicata (P. and R.) J. Agardh   sli. c
69. Hedophyllum sessile (Agardh) Setchell   lli, va
70. Hedophyllum subsessile (Areschoug) Setchell   sli. r
71. Laminaria bullata Kjellman   sli, va
72. Laminaria bullata subsimplex Setchell and Gardner   lli, r
73. Laminaria saccharina (L.) Lamouroux   sli. c
74. Laminaria andersonii Farlow   sli, vr
75. Chordaria abietina Ruprecht   lli. r
76. Leathesia difformis (L.) Areschoug   li, r
77. Desmarestia ligulata (Lightfoot) Lamouroux   sli. r
78. Desmarestia ligulata herbacea (Turner) J. Agardh   sli. a
79. Desmarestia aculeata (L.) Lamouroux   sli. c
80. Soranthera ulvoidea Postels and Ruprecht   lli. c
81. Phyllitis fascia (Mueller) Kützing   sli. vr
85. Scytosiphon lomentarius (Lyngbye) J. Agardh   sli. vr
83. Colpomenia sinuosa (Roth) Derbes and Solier   li. c
84. Coilodesme californica (Ruprecht) Kjellman   sli. r
85. Punctaria latifolia Greville   sli. r
86. Ectocarpus siliculosus typicus Kjellman   sli. r

CHLOROPHYCEAE

87.	Codium mucronatum J. G. Agardh	lli, r
88.	Codium adhaerens (Cabr.) Agardh	lli, r
89.	Bryopsis hypnoides Lamouroux	lli, vr
90.	Cladophora arcta (Dillwyn) Kützing	lli, a
91.	Cladophora scopaeformis (Ruprecht) Harvey	lli, r
92.	Cladophora spinescens Kützing	lli, c
93.	Rhizoclonium sp.	li, r
94.	Chaetomorpha sp.	uli, vr
95.	Hormiscia tetraciliata Frye and Zeller	lli, c
96.	Monostroma fuscum (P. and R.) Wittrock	sli, r
97.	Ulva lactuca L.	sli, va
98.	Enteromorpha linza (L.) J. Agardh	lli, va
99.	Enteromorpha intestinalis (L.) Link.	lli, a
100.	Enteromorpha clathrata (Roth) Greville	lli, e
101.	Enteromorpha prolifera (Fl. Dan.) J. G. Agardh	lli, r
102.	Chlorochytrium inclusum Kjellman	sli, c

MYXOPHYCEAE

103.	Dermocarpa fucicola Saunders	li, c
104.	Calothrix crustacea Thur.	uli, c
105.	Anabaena variabilis Kützing	uli, r
106.	Cylindrospermum stagnale (Kützing) Bornet and Flahault	uli, r

List of Localities to Which Reference Is Made in This Paper

Argyle Lagoon. A small triangular lagoon about one mile south of the Puget Sound Marine Station. It is almost dry at low tide (*Plate 10, Lagoon No. 4*).

Andrews Bay. About two miles south of Mitchell Bay, on the west coast.

Brown Island. A small island in Friday Harbor on the eastern shore of San Juan Island, opposite the Puget Sound Marine Station.

Cattle Point. A high peninsula which forms the extreme southeastern portion of San Juan Island. The position of the point is Latitude 48° 27′ N. and Longitude 122° 58′ W.

Deadman's Bay. About midway between Roche Harbor and Cattle Point on the west shore. Its position is Latitude 48° 31′ N. and Longitude 123° 08′ W.

Dinner Island. A small island in North Bay.

Eagle Point. A steep rocky point about midway between False Bay and Cattle Point.

False Bay. On the southwest coast. This bay has a shallow sandy bottom which is entirely exposed at low tide. It is about three-fourths of a mile long and one-half mile wide.

Friday Harbor. A harbor and village, the latter being the county seat of San Juan County, situated on the eastern shore about midway from the southeast and northwest points.

Garrison Bay. A narrow bay on the northwest coast.

Goose Island. A small, dry, wind-swept island near the shore of Cattle Point.

Griffin Bay. A large bay on the southeast shore between Cattle Point and Madrona Peninsula.

Idlewild. See Newhall's Point.

Illinois Inlet. A narrow body of · water extending into the north side of Cattle Point, named by the writer in honor of the state of Illinois on account of its representation at the Puget Sound Marine Station (*Plate* 10).

Kanaka Bay. A small, rock-bound bay, west of False Bay. It forms a harbor for fishermen and is a favorite collecting place for biology students.

Kansas Cove. A large cove inside of Turn Island on the east shore of San Juan Island. This cove has a gravel bottom and is a favorite place for dredging seaweeds. Named by the writer in honor of the State of Kansas, which has been represented at the Puget Sound Marine Station for many summers (*Plate* 10).

Lime Kiln. A little bay and lime kiln located near Deadman's Bay on the west coast. Several limestone ledges project into the water.

Limestone Point. The northeast point of the island, formed of limestone.

Madrona Point. A point on the north side of Madrona Peninsula opposite Brown Island (*Plate* 10).

Madrona Peninsula. A large peninsula which lies between North Bay and Friday Harbor. Named by the writer because of the large number of Madrona trees (*Arbutus menziesii*) which line its shores (*Plate* 10).

Minnesota Reef. The name given by Professor Josephine E. Tilden of the State University of Minnesota in 1898 to a ledge of rocks more or less uncovered at low tide, on the eastern extremity of Madrona Peninsula, opposite Turn Island (*Plate* 10).

Mitchell Bay. On the northwest coast between Andrews Bay and Garrison Bay.

Nebraska Springs. A group of small springs along the steep rocky shore at the foot of South Hill. Named by the writer in honor of the State of Nebraska, for her representation at the Puget Sound Marine Station (*Plate* 10).

Newhall's Point. (Idlewild). A small point in Friday Harbor named in honor of Mr. Newhall. Formerly it was the site of the residence of "Judge" Warbass, who called it "Idlewild."

North Bay. A small bay in the north end of Griffin Bay.

O'Neil Island. A small island in Rocky Bay on the northeast coast.

Pear Point. A point on the south side of Madrona Peninsula.

Pile Point. A rocky point located about one mile west of Kanaka Bay.

Point Caution. A point directly north of Friday Harbor. The shore is rocky and is washed by swift tide currents.

Roche Harbor. A small village and harbor on the northwestern shore of San Juan Island.

Rocky Bay. On the northeast coast south of Limestone Point.

Smallpox Bay. (Smugglers Cove). A small cove just south of Andrews Bay, on the west coast.

Smugglers Cove. See Smallpox Bay.

Turn Island. A small rocky island off the extreme east coast of Madrona Peninsula.

Turn Rock. A small reef which is exposed only at low tide, east of Turn Island. The tide turns very suddenly and forms very swift currents, so that the rock is difficult to approach except at favorable tides.

Utah Rock. A large rock which is almost covered at high tide, just outside of and along the southwest shore of False Bay. Named in honor of the state of Utah (*Plate* 10).

Westcott Bay. A long bay just south of Roche Harbor.

White Point. A narrow irregular point between Roche Harbor and Westcott Bay, on the northwest coast of San Juan Island.

SUMMARY AND CONCLUSIONS

1. The rocky shores of San Juan Island possess a very dense algal flora.

2. The sandy beaches and bays are almost free from algal vegetation.

3. The algal vegetation from the high tide line to the *Nereocystis* beds is composed of four distinct associations, which are named after

one of the most dominant species in each association.   *Zostera* forms an association in the shoal water of bays.

  1.   Endocladia association.

  2.   Fucus association.

  3.   Ulva association.

  4.   Laminariaceae association.

  5.   Zostera association.

   4.   The number of species common to each association increases in the lower associations.

   5.   The algae in general are larger in the lower than in the higher associations.

   6.   The different groups of algae are not restricted to any definite associations.

   a.   Rhodophyceae, Phaeophyceae and Chlorophyceae are found in each of the four associations, therefore it is evident that Agardh's (1) three zones of algae, viz., red, brown and green, do not hold.

   b.   Rhodophyceae are found almost equally distributed in the different associations.

   c.   Phaeophyceae are most abundant in species in the Laminariaceae association.

   d.   Chlorophyceae are most abundant in the Ulva association.

   e.   Myxophyceae are represented only by a small number of marine species.

TABLE 8.   *Showing number of species in each association*

	Myxophyceae	Chlorophyceae	Phaeophyceae	Rhodophyceae	Total
Endocladia Association	3	3	1	6	13
Fucus Association	1	1	4	9	15
Ulva Association	0	9	3	12	24
Laminariaceae Association	0	1	19	7	27

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Gas Pressure in Nereocystis

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So far as the writer has been able to find there is no literature on the gas pressure within the air cavities of marine algae. Yet daily contact with *Nereocystis* soon makes it evident that the pressure inside the plant is not usually the same as that outside.

The air cavity of *Nereocystis* is estimated by Zeller and Neikirk[1] to have a volume of about 4 liters or less, depending upon the size of the plant. Normally the bulbous end either floats on the surface of the water or is submerged below it, depending upon the tides, the length of stalk produced by the individual, and the depth of the water.

Fallis[2] and Sheldon[3] have shown that the plant is independent of its holdfast, also that its parts are largely independent of each other. The most serious thing about cutting or otherwise injuring it, seems to be the paving of the way for the entrance of bacteria.

We have, therefore, a plant containing a great quantity of gas, living in a medium whose temperature changes little, a plant which may be torn loose and moved about freely without stopping or materially hindering its growth, and which may be greatly injured without seriously affecting its physiological activities. These conditions seemed favorable for experimenting on the gas pressure within the bulb. Experiments were undertakeng during July, 1915, at the Puget Sound Marine Station, to determine the variations in pressure within the gas cavity.

The apparatus used was essentially a U-tube half full of mercury, with some form of puncturing apparatus to connect it with a kelp. At first a continuous glass tube was bent to form the whole apparatus, together with the puncturing tip. But this was so difficult to handle from a rowboat, and thus so often broken, that it was abandoned. In the final form a pressure rubber tube of small bore was used to connect the kelp with the U-tube. The difficulties of exact measurements on the bobbing boat were such that no difference could be observed between the results of the two kinds of apparatus. The small amount of gas in the

[1] Zeller, S. M., and Neikirk, Abigail. Gas exchange in the pneumatocyst of Nereocystis. Puget Sound Marine Sta. Pub. 1:25-30. 1915.

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tube constituted a very small proportion of the total gas when the con-
nection was made. Nor could any difference be observed when the two
forms of apparatus were used fastened to a raft. The puncturing ap-
paratus was merely a small glass tube drawn out to a sealed point in
the side of which, at a distance of one or two inches from the tip, a hole
was blown.

The pressure was recorded from a rowboat, in 1000 kelps under
various natural conditions at various times of day and night, in order
to get the average. Variations in atmospheric pressure were not taken
into account, since neither the apparatus nor the conditions of reading
would permit great accuracy. The pressure varied from plus 124 mm.
of mercury more than atmospheric pressure to 316 mm. less than at-
mospheric pressure, with an average of 77.3 mm. less than atmospheric
pressure. The variation, therefore, was 440 mm. of mercury, or about
.58 of an atmosphere. The kelps were taken regardless of size or con-
dition of leaf, so the average of a bed would be approximated. The
average of the larger, healthier plants falls nearly to 200 mm. of mer-
cury below atmospheric pressure.

During the course of these readings it became apparent that (a)
the time of day, (b) the condition of submergence and (c) the health of
the kelps, were factors in determining the pressure. Afternoon readings
always averaged higher than forenoon readings. Submerged kelps
showed a lower average pressure than those whose air cavities projected
above the surface of the water. Healthy abundant leaves were coninci-
dent with low pressures. Further experiments on the effect which these
conditions have on the gas pressure were then undertaken.

In explanation, it should be said that the fronds of mature *Nereo-
cystis* plants vary from approximately 25 feet to 2 feet in length and in
number from approximately 50 to none at all. The fronds grow mostly
near their bases, while at their tips they are frayed, decomposed and
eaten by parasites. Their length depends upon the rate of growth in
proportion to the number and activity of the parasites upon them. The
fronds are commonly 4 or 5 inches wide and thus have something like
99% of the area of a large, whole plant. Their loss, therefore, makes
a great change in the plant. According to Peters, a snail is one of the
most effective causes of the loss of fronds.

To test the effect of loss of fronds on pressure within the air cavity,
100 healthy-looking frondless, and 100 healthy-looking frondose plants
were tested for pressure at various times. At each time of testing the
same number of each were tested, so as to eliminate error due to diurnal

4Peters, Rupert. A preliminary study of the causes that produce "bald-
headed" kelp. Kan. Univ. Sci. Bull. 9:1-10. 1913.

effect; and the plants were selected from those having their air cavities sugmerged, so as to avoid changes due to air temperature. The average pressures within the frondless plants was 42 mm. of mercury below that of the atmosphere, and within the frondose ones 184 mm. of mercury below; a difference in pressure of 142 mm. or roughly 1/5 of an atmosphere. These average lower than the general run of plants because the most healthy looking specimens were selected. The results plainly indicate that possession of fronds is a condition which must be considered in connection with the lowering of the pressure within the air cavity (*Plate* 16).

To test further the effect of the fronds, frondose kelps were fastened to a raft in such a manner that they would remain submerged. They
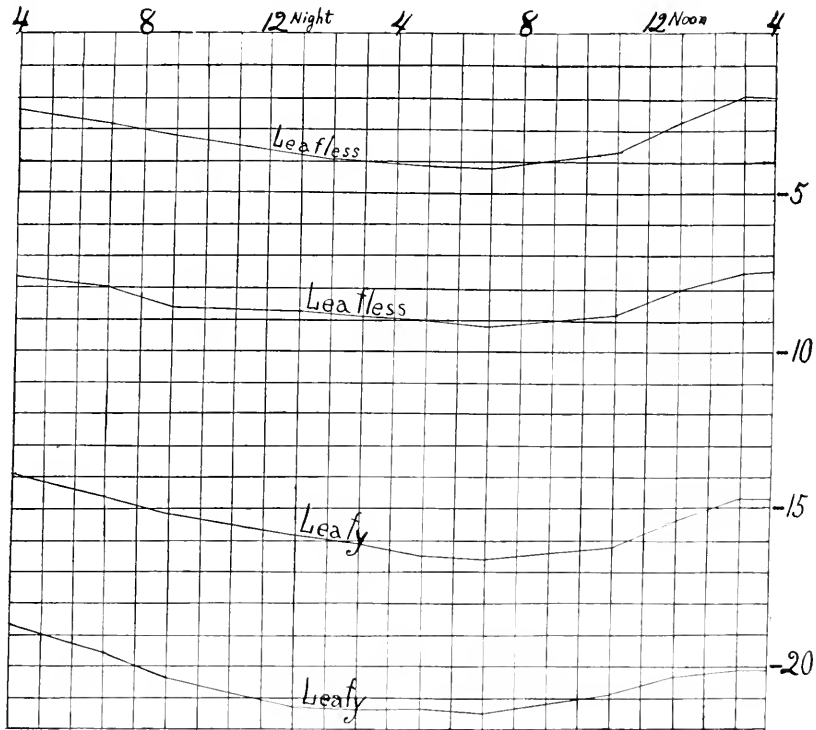
PLATE 16

The variations in pressure in four plants during a period of 24 hours. Also shows the difference in pressure between frondose (leafy) and frondless (leafless) plants. Figures at the right indicate displacement of mercury column. Figures at top indicate hours of the day.

were then connected with a pressure apparatus, and records taken from 5 P. M. to 11 A. M. at intervals of two hours to see that the plants were normal. The fronds were then cut off leaving about 1 inch to

stump, after which observations were continued for 19 hours and showed a gradual increase in pressure beginning within six hours. This suggests that the fronds use the gases within the air cavities.

At the same time 100 frondose plants were experimented upon to test submergence as a factor affecting the pressure within the air cavities. The most healthy looking and vigorous plants were selected. These were tested for pressure and gave the following averages:

Submerged, 184 mm. of mercury below that of the atmosphere.
Floating, 166 mm. of mercury below that of the atmosphere.
Difference, 18 mm. of mercury, or about .023 of an atmosphere.

Evidently submergence is a factor, but not so potent as the possession of fronds. From the fact that the water at the surface is slightly warmer it is presumably the difference of temperature which causes the change in pressure.

To test diurnal variations, plants were fastened to a raft so they remained submerged and in good condition, and their pressure recorded at intervals of a few hours during day and night. The results show that the time of lowest pressure is about 7 A. M. and that of highest pressure about 3-4 P. M. (*Plate* 16). The diurnal variation of the plants thus experimented upon averages 16 mm. of mercury. This variation in pressure is probably due to changes in temperature, for the plants were submerged in sea water whose variations in temperature coincided almost always with the variations in pressure within a given air cavity.

SUMMARY

1.   The gases within the air cavity average about 77 mm. of mercury below air pressure.

2.   The loss of fronds causes a rise of pressure within the air cavity until it approaches or even exceeds that of the air.

3.   There is also a fall of pressure at night, and a lower pressure in submerged plants. These reductions are likely due to changes in temperature.

Effect of Light on the Development of Young Salmon

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Introduction

Fish-hatchery men in the course of their work have made observations upon the influence of light on the young fish during the periods of hatching and early growth, and are almost unanimous in their opinion that the young fish thrive better in darkness than in light. They have noticed a restless activity in the light that is not compatible with the best and most rapid development. As a result the hatching troughs are painted black and are kept in buildings in which the light may be regulated by window shades. In recent years the hatchery superintendents, at least of the west coast, have kept the eggs and alevins as much in the dark as possible. The fish are held in the hatching troughs until the yolk is absorbed, after which those that are retained (and the majority are retained) are turned into feeding ponds, a greater number of which are now kept under cover so as to cut out all direct light. It was with the purpose of determining more definitely the influence of light on the young fish that the experiments recorded in this paper were undertaken.

Equipment and Methods

The work was begun at the Puget Sound Marine Station at Friday Harbor, Washington, but the laboratory observations were carried on in a small fish hatchery upon the campus of the University of Washington during the season of 1914-1915. The fish troughs and baskets were of the type commonly used in the hatcheries of the State of Washington and each of the troughs held five baskets. The troughs were arranged as shown in plate 17.
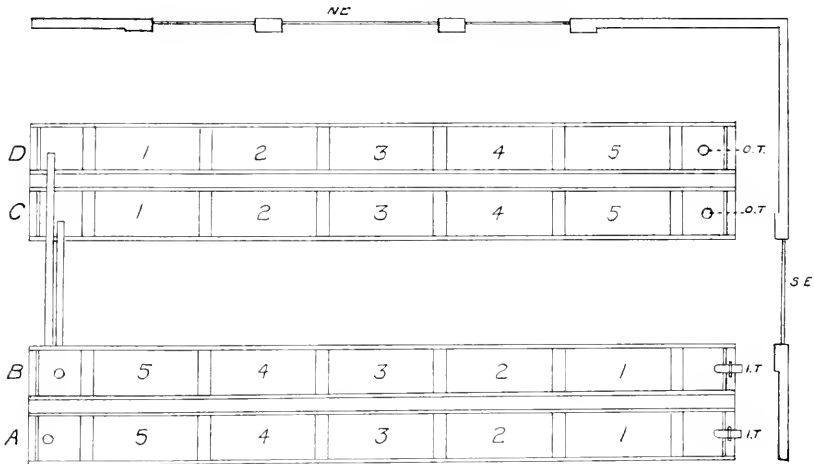
PLATE 17

Diagram of the arrangement of troughs and water supply. Troughs A and D were painted black on the inside, while troughs B and C were painted white. Troughs A and B receive independent supplies of water through pipes marked I. T., each pipe having a stop cock by means of which the rate of flow could be regulated. The water was conducted by means of pipes from the lower ends of A and B to the upper ends of C and D respectively.

The room containing the troughs (*Plate* 17) was lighted by three windows on the northeast and one on the southeast, those on the northeast contained thirty square feet of glass and the one on the southeast nine square feet. The troughs were placed quite close to the windows, the relation being indicated in the diagram. No window-shades were used to regulate the amount of light that fell upon the troughs. During the winter months the sky was clouded for a considerable portion of the time and not much light found its way to the hatching troughs. In addition to the varying light of day, two 60-watt tungsten electric lamps were kept lighted day and night throughout the period of observation. These lights were provided with cup-shaped reflectors and for the first four months were kept within one foot of the surface of the water in the sections of the trough in which the fish were to be under the influence of light. After this period the lights were raised to about four feet above the water.

The water used was taken from that supplied to the City of Seattle by the Cedar River. This water is of glacial origin and very pure. The temperature varied with the season. Starting October 31, the date when the eggs were placed in the hatchery, the water had a temperature of $13°C$. It gradually lowered up to December 21, when the thermometer registered $5°C.$, at which temperature it remained for about six weeks. About this time it began to rise slowly and continued rising until it reached a maximum of $21°C.$ in August.

The principal observations were made on the eggs and young of the Chinook salmon (*Oncorhynchus tschawytscha*), and a check experiment was made on the eggs and young of the humpback salmon (*Oncorhynchus gorbuscha*).

The eggs of the Chinook salmon were spawned September 27, at the State hatchery located at Auburn, Washington, and were brought to the hatchery on the campus October 31. The eggs, over 8,000 in number, were taken from one basket and were less than half of the number contained in the basket. All the eggs were spawned the same day and were so thoroughly mixed, that the fact of the eggs being taken from several females would not in any degree affect the results of the experiment. On their arrival at the campus hatchery the eggs were divided into two lots and placed in separate baskets. These were placed in compartments numbered 2 and 3 in the trough A. An estimation of the number of eggs in each basket, based on measurement, showed that the basket in No. 2 contained 3,800 eggs and the one in No. 3 contained 4,520. The basket in No. 3 was covered up so as to exclude almost all light, while that in No. 2 was left uncovered and a 60-watt tungsten light was suspended over it at a distance of about one foot from the surface of the water, a cup-shaped reflector directing nearly all the light into the water.

Observations During Hatching Period

For a few days previous to hatching it was observed that the embryos in the light were much more active than those in the dark. Hatching began November 15 with the water at a temperature of 10.5°C. During the first four days the numbers hatched were quite small in both baskets, but during the next ten days the entire number were hatched. Each day, beginning November 20, the eggs in each basket were measured in order that the number hatched during the previous twenty-four hours could be approximately determined (*Table* 1). A glance at table 1 shows that the fish in the light hatched more quickly than those in the dark. During the period from November 15 to November 21

TABLE 1. *Number of fish hatched each day in light and dark troughs*

	IN LIGHT TROUGH		IN DARK TROUGH		
Date	No. hatched	Percent. of total	No. hatched	Percent. of total	Temperature Centigrade
Nov. 20	680	17.89	560	12.38	9.75
" 21	1160	30.52	975	21.57	10.
" 22	790	20.79	995	22.01	10.
" 23	510	13.42	600	13.27	10.
" 24	380	10.00	610	13.49	10.
" 25	240	6.31	500	11.06	10.
" 26	30	.79	180	3.98	10.
" 27	10	.26	78	1.72	10.4
" 28			22	.48	10.4

the per cent of those hatched in the light was 48.41 and of those hatched in the dark only 33.95. By November 23, 82.62 per cent of those in the light were hatched, while 69.23 per cent of those in the dark were hatched. It was also observed that those in the light quickly wriggled out of the shells and passed between the wires of the basket to the bottom of the trough, while those in the dark were slow to separate themselves from the shells. During the period of more active hatching many in the dark were seen lying partly in and partly out of the shell, while in the light very few were seen in this condition. Light hastened the hatching of the embryos.

Observations During Yolk-Sac Stage

The fish that had been hatched in the light were removed December 15 to section 3 of trough B (*Plate* 17) which was painted white, and the 60-watt light placed directly over them within one foot of the surface of the water. Shortly after this the fish in the light became markedly active and swam to the upper part of the trough where the large majority of them remained for the next 10 days, after which they distributed themselves fairly uniformly throughout the water of their compartment. This free-swimming condition they kept from this time onward.

Those in the dark remained quiescent for two weeks longer than those in the light and were massed together at the lower end of the compartment in which they were kept, being carried there by the current of the water in the trough. At the end of the two weeks they became more active and sought the upper end of their compartment. Within four days from the time of the beginning of this activity they had distributed themselves quite uniformly throughout the water, but they did not exhibit the same degree of activity as those that were kept in the light.

About January 8 it appeared that those in the dark trough were a little larger than those in the light trough. In order to verify this a number of weighings were made. In weighing the fish a beaker containing about 50 cc. of water was accurately balanced on the scales, then the fish were scooped up at random with a large sized coffee-strainer, in numbers varying between 45 and 66 at each sweep. The bottom of the strainer was wiped comparatively dry with a cotton cloth, the flopping of the fish causing most of the water to pass through the strainer. The fish were then put into the beaker, which was again accurately balanced. As this method would give rise to slight errors, a large number of fish were weighed in several lots in order to reduce this inaccuracy to a minimum. Table 2 records the weights of five such lots of fish from each trough. The difference in the average weight was 40 mg. in favor of those developed in the dark. Thus up to this time those developed in the dark weighed

TABLE 2.   *A comparison of the weights of fish taken Jan. 8*

Group	No. of fish from light	Weight in grams	No. of fish from dark	Weight in grams
1	66	28.830	46	20.500
2	58	19.550	60	27.140
3	49	20.660	53	24.070
4	45	19.130	56	24.400
5	61	25.200	66	29.150
Total	279	113.370	281	125.260
Average	1	.406	1	.446

9.85 per cent more than those developed in the light. The next day, January 9, 12 fish were picked at random from each trough and accurate measurements were taken as follows: length from tip of snout to base of middle ray of caudal fin, greatest depth, greatest thickness, length and width of ventral yolk-sac opening.

The length of those living in the light varied between 30 and 33.5 mm. with an average of 31.1. The greatest depth, which was through the center of the yolk-sac, varied between 6.3 and 7.7 mm. with an average of 7.1; the greatest thickness varied between 4.7 and 5.6 mm. with an average of 5; the ventral opening of the yolk-sac varied in length between 8 and 10 mm. with an average of 9.2, and the greatest width of this opening varied between 1.2 and 4.2 mm. and averaged 2.6.

The length of those taken from the dark varied between 29 and 33 mm. with an average of 31.5; the depth varied between 7.2 and 8.5 mm. with an average of 7.9; the thickness varied between 5 and 6 mm. with an average of 5.4; the length of the ventral yolk-sac slit varied between 9 and 10.7 mm. with an average of 9.9; and the greatest width of the slit varied between 2.4 and 5.5 mm. with an average of 4.1.

These figures show an average difference in size in favor of those kept in the dark of .4 mm. in length, .8 mm. in greatest depth and .4 mm. in greatest width. The yolk-sac opening averaged .7 mm. longer and 1.5 mm. wider in those from the dark than in those from the light. The difference in breadth and thickness between those in the dark and those in the light indicated that there was a considerably greater absorption of yolk material by those in the light.

In order to determine this difference accurately 12 fish were taken at random from each trough on January 18 and placed in a five per cent solution of formalin for seven days. At the end of this time the yolks were so hardened that they could be easily separated in mass from the fish. The fish were dried first on a linen towel and then carefully on filter paper. The 12 from the dark trough weighed 6.240 grams and the 12 from the light trough 5.820 grams. The yolk-sacs were then carefully dissected out and those of the 12 fish from the dark trough weighed .930 grams, while those of the 12 from the light weighed .790. From these

weights it was determined that the unabsorbed portion of the yolks of the 12 fish from the dark was 17.72 per cent heavier than that of the 12 from the light; at the same time the 12 fish from the dark without their yolk-sacs weighed 5.310 grams, and the 12 from the light without their yolk-sacs weighed 5.030 grams, a difference of 5.57 per cent in favor of the fish from the dark over those from the light. Thus, although there is much less yolk absorbed by the fish in the dark, there is yet a greater weight of organized tissues.

Weight comparisons were again made January 18. About 50 fish were taken by a single sweep of the strainer from each trough and 40 were picked at random from each of these groups. The fish were first dried on a linen towel and then on filter paper. The 40 taken from the dark trough weighed 19.03 grams, and the 40 from the light trough 17.30 grams. According to these weights the 40 from the dark trough weighed 10 per cent more than the same number from the light.

The following day a dozen fish were taken from each trough at random and measurements taken similar to those made January 9. Table 3 records the maximum and minimum dimensions between which they varied, with the average for each group. Of those taken from the

TABLE 3.   *The dimensions of fish from each trough compared*

Group	Length varied in mm. between	Average in mm.	Depth in mm. varied between	Average in mm.	Thickness in mm. varied between	Average in mm.
Fish from dark	32 and 35.5	33.4	6 and 7.5	6.9	4 and 5	4.8
Fish from light	30 and 36	32.6	6 and 7.5	6.5	4 and 4.5	4.1
Differences in averages		.8		.4		.7

dark two fish had their ventral slits closed, in the remainder the slits varied in length between 6 and 9 mm., and in width between .6 and 2 mm., the average dimensions of the openings including the two fish with the closed slits being 6.1 mm., in length and .8 in width. Of those taken from the light eight had the ventral slit entirely closed and in the remaining four it was all but closed. These figures confirm the statement previously made, that a much greater yolk absorption took place in the fish kept in the light.

The last determination of comparative weights before feeding began was made January 29. Forty fish taken at random from each trough gave the following results: those from the dark trough weighed 21.39 grams and those from the light trough 19.22. These weights show that the fish

from the dark weighed 11.28 per cent more than those from the light. It is evident from the foregoing estimates, admitting some possible error due to methods of removing water, that fish developed in the dark through the yolk-sac stage have a very decided advantage over those kept in the light.

Chemical Analysis of Fish

It was deemed important to determine just wherein the difference in weight lies. To this end a careful analysis was made to find the relative amounts of water, protein, fats, and ash in the fish of each trough. Fifty fish were taken at random from each trough shortly before feeding began. They were very carefully dried by the use of linen toweling and filter paper after which they were exposed to the atmosphere until all visible moisture had disappeared from the surface. Those from the dark trough then weighed 26.8422 grams, and those from the light 24.4216, the fish from the dark being practically 10 per cent heavier than those from the light. The fish were now placed in an electric incubator kept at a temperature of 100°C., until all water was evaporated. The dried material was then pulverized and carefully extracted with ether in a soehlet apparatus until all oil was removed. The residue was then burned until nothing but the white ash remained in the platinum crucible. Table 4 shows the weights in grams of the different substances in each group of

TABLE 4. *The relative weights of substances in each group of fish*

	Total weight	Weight of water	Weight of protein	Weight of fat	Weight of ash
50 fish from dark	26.8422	22.0258	3.5737	1.0705	.1722
50 fish from light........	24.4216	19.9712	3.3014	.9952	.1538
Difference	2.4206	2.0546	.2723	.0753	.0184

50 fish. It is evident that water makes the great difference in weight between the two groups of fish, but when we compare the per cents of substances in each group we find but a very small relative difference (*Table 5*).

TABLE 5. *Per cents of substance in each group of fish*

	From dark	From light	Difference	In favor of fish from the
Water	82.056	81.776	.280	Dark
Protein	13.314	13.518	.204	Light
Fat	3.988	4.075	.087	Light
Ash	.642	.629	.013	Dark

Looking at the relations from this standpoint the difference in per cents of water between the two groups of fish is less than one-third of one per cent while the differences in the other materials are still less. So, from this viewpoint, the relative amounts of material in each group are almost identical.

Experiment on Metabolism in Light and Darkness

More light was thrown upon the influence of activity on metabolism by an experiment made on fishes taken from each trough January 12. At this time the ventral slits had not closed over the yolk-sacs in either group, so that conditions from the standpoint of nutrition would be about the same for both groups. Twelve fish of uniform size were picked from the light trough and placed in a flask which contained 1230 cc. of water taken from the pipe that supplied water to the troughs. A rubber cork was inserted tightly leaving practically no air space in the neck of the flask. The fish were placed in this flask at 10:17 P. M., and three minutes later 12 fish of similar size were taken from the dark trough and placed in a flask containing the same amount of water from the same source. This flask was corked in the same way as the other. During the entire experiment the temperature of the water in either flask did not vary one degree from $7°C$. The two flasks were placed just outside a window, the first one being left in the light while the second was placed in a box from which all light was excluded. The window faced the south so that the direct light of the sun fell on the flask in the open during the day; while during the night a thirty-two candle power electric light, mounted in a cup-shaped reflector and placed about two feet from this flask, threw a strong light upon the fish. No disturbing influence other than the occasional presence of the observer entered into the experiment, and the fish being used to daily care were indifferent to the observer's movements.

The flasks containing the fish were placed outside the window at 10:35 P. M. and were under observation for nearly an hour. During this time the fish in the light continued to swim about vigorously in the lower strata of water. Several observations were made of those in the dark during this hour and they were found every time to be lying at the bottom of the flask with scarcely any movement. Even if brought into the light those fish accustomed to the dark did not become active like those kept all the time in the light. At first they darted about but soon settled down to the bottom in a state of inactivity.

At 9 A. M. the next day 12 more fish from the light trough were placed in an open flask of similar size and filled with water. This flask was placed in the light beside the first one. These were to be used as a control. The fish that had been in the light all night were at this time swimming about with great activity and kept up a darting movement from the lower to the higher levels of the water and then back again, occasionally seeking air at the surface of the water in the neck of the flask. They exhibited a considerable degree of restlessness not observable in those of the control. Their respiratory movements were 60 to the

minute.   Observation of those in the dark showed them to be lying on the bottom of the flask almost without motion. and showing no symptoms of being uncomfortable.   Their respiratory movements were but 50 to the minute.

At 9:30 A. M. those in the light were decidedly more restless and were frequently seeking air at the surface of the water.   They still possessed perfect power of control and oriented themselves in a normal way. No change was observable in those in the dark.

At 10:30 A. M. observations were again made.   Those in the light showed a decided tendency to keep in the upper strata of the water while those in the control remained in the lower.   Those upon which the experiment was being made were not orienting themselves in a normal way.   Instead of maintaining a horizontal position they floated with the longitudinal axis of the body at a considerable angle to the horizon.   At 10:45 their respiration movements were 67 per minute.   Those in the dark showed no signs of being uncomfortable at this time.

At 12:55 P. M. those in the light were fast losing the power to direct their movements normally.   They darted about in an uncertain way and as they settled on the bottom turned on their sides.   In the dark flask the fish were beginning to show signs of uneasiness and were seeking the upper strata of the water, but there was no signs of exhaustion.

At 2:25 P. M. those in the light were showing very marked signs of exhaustion.   Five were floating in the neck of the flask at the surface of the water.   The remaining ones were constantly darting to the upper part of the flask and then settling downward tail first to the bottom where they lay on their sides.   Their respirations had increased to 94 per minute.   Those in the dark showed little disposition to swim about actively.   They occasionally went to the surface.   Their loss of power to move in a normal way was not so marked as that of those in the light two hours before.   Their respiratory movements were 89 per minute.   At 3 P. M. those in the dark exhibited about the same degree of exhaustion shown by those in the light at 12:55 P. M.

At 4 P. M. those in the light were lying in a helpless and dying condition on the bottom. while those in the dark were in a condition similar to that shown by the fish in the light at 2:25 P. M.   There can be no doubt but that the greater activity on the part of the fish in the light resulted in a more rapid exhaustion of the oxygen contained in the water, and a greater production of the waste products of metabolism which would lead to the earlier exhaustion of the active fish.   It would seem, therefore, a fair conclusion to draw from this experiment that activity is one of the most important factors in bringing about the difference in weight between the two groups of fishes.

Results After Feeding Began

Food was first given to the fish on February 1. It consisted of boiled pig's liver ground up very finely, to which for a couple of weeks, was added hard boiled hens' eggs. The fish showed a marked preference for the egg and ate it greedily. The fish were fed but once a day and that not at the same hour of the day. Sometimes the feeding was done in the morning, sometimes at noon and sometimes in the evening. The fish would in all probability have done much better if they had been fed regularly twice a day. But since both lots of fish were treated in exactly the same way the results of this experiment would not be affected by irregularity in feeding.

It was impossible to determine whether the fish received the same amount of food per capita as a considerable amount was swept away by the water. In order to be assured that the fish had similar treatment, more food was given them each time than they ate, so that at the next feeding time there remained in the troughs a considerable amount of food from the previous feeding. This refuse was as a rule removed before fresh food was again given to them. From this time until July 1 the black trough was covered with a board, a narrow crack being left along the side of the trough away from the light. This was done in order that the fish might have enough light to enable them to see their food.

Another determination of relative weights was not made until March 13. On this date 15 fish were taken from the dark trough with one sweep of the strainer, and in a similar way 36 were taken from the light trough. Table 6 gives the results of this determination. By reducing the relation

TABLE 6.   *A comparison of the weights of fish taken Mar. 13*

	No. of fish	Total weight in grams	Average weight in grams
Fish from dark	45	32.100	.7133
Fish from light	36	22.290	.6192
Difference in average weights....			.0941

of the average weights to a percentage it is shown that the fish from the dark weighed 15.2 per cent more than those from the light.

The next determination of relative weights was made March 24. The method of taking and drying the fish was the same as that previously used. In table 7 the results are recorded. In this case the fish from the dark trough weighed 16.33 per cent more than those from the light.

TABLE 7.   *A comparison of the weights of fish taken Mar. 24*

Group	No. of fish	Total weight in grams	Average weight in grams
Fish from dark	35	29.120	.8320
Fish from light	25	17.880	.7152
Difference in average weights			.1168

About the first of April the fish were transferred from troughs A and B to D and C respectively (*Plate* 17). They now occupied, in each trough, sections 3, 4 and 5, the partitions separating these sections having been removed. Those in C were in a white trough and kept constantly in the light as they had been in B, while those in D were in a black trough and covered from the light.

With a view to obtain, if possible, a more accurate average weight it was determined to weigh a larger number of fish from each group; accordingly on April 6, 150 fish were taken at random from each trough and after drying uniformly were carefully weighed. The comparative weights are given in table 8. According to these figures the percentage

TABLE 8. *Comparative weights of fish taken Apr.* 6

Group	No. of fish	Total weight in grams	Average weight in grams
Fish from dark	150	127.0600	.8471
Fish from light	150	110.0500	.7336
Difference in average weights ..			.1135

of difference is less than in the previous estimate being only 15.47 in favor of the fish from the dark, over those from the light.

Twenty-five fish were picked at random from each of these last groups and measurements made. In table 9 are recorded the maximum and minimum dimensions between which the fish varied, together with the average

TABLE 9. *A comparison of the dimensions of 25 fish from each group group in table* 8

Group	Length in mm. varied between	Average in mm.	Depth in mm. varied between	Average in mm.	Thickness in mm. varied between	Average in mm.
Fish from dark	38 and 45	40.44	7.5 and 9	8.25	4.8 and 6	5.19
Fish from light	35 and 41	37.92	5.8 and 9	7.21	3.6 and 5	4.60
Difference in averages		2.52		1.04		.57

of each dimension. The figures show not only a very decided difference in size between the maximum and minimum dimensions within each group, but also indicate an increasing irregularity in growth, the largest from the dark trough being 18.42 per cent longer than the smallest, and the largest from the light 17.14 per cent longer than the smallest.

Another estimate of relative weights and growth was made April 9, again using large numbers of fish. The fish were placed in a four per

cent solution of formalin and three days later, after carefully drying them, they were weighed. These weights are recorded in table 10. The

Table 10. *A comparison of the weights of fish taken Apr. 9*

Group	No. of fish	Total weight in grams	Average weight in grams
Fish from dark	195	178.700	.9164
Fish from light	218	169.300	.7766
Difference in average weights ...			.1398

average weight of the fish from the dark trough according to these estimates is 18 per cent greater than that of the average weight of those from the light.

The increasing unevenness in growth is well brought out in a comparison of the weights of the 10 largest and the 10 smallest from each group last taken from the troughs:

```
The 10 largest from dark weighed ...... 12.290 grams
The 10 smallest from dark weighed ......  6.440 grams
The 10 largest from light weighed ...... 10.390 grams
The 10 smallest from light weighed ......  4.750 grams
```

The 10 largest from the dark trough were 90.83 per cent heavier than the 10 smallest from the same trough, while the 10 largest from the light trough were 118.73 per cent heavier than the 10 smallest from the light. From these figures it is seen that the fish in the dark not only average larger but they are more uniform in size.

With a view to eliminating as far as possible any error that might arise from the method of removing the water and the chance that a single sweep of the strainer might take a group of fish not representing the average in each trough, a still larger number were weighed April 10. This time nine different groups were weighed, each being taken by a single random sweep of the strainer. The fish were weighed alive and each group weighed was returned to the trough from which it had been taken before the next group was caught. It is probable that many of the fish were weighed more than once. Table 11 gives the result of this

Table 11. *Comparative weights of a large number taken from each group Apr. 10*

	FISH FROM DARK TROUGH		FISH FROM LIGHT TROUGH	
	No. in each group	Weight in grams	No. in each group	Weight in grams
	98	86.750	111	86.670
	114	100.100	97	71.250
	114	100.470	112	98.500
	117	105.520	123	99.800
	89	81.270	107	81.200
	83	78.470	110	83.720
	131	122.740	107	81.320
	115	102.270	117	90.050
	108	94.730	133	102.530
Totals	969	872.320	1017	786.040

weighing. The average weight of those from the dark trough was .9002 gram and of those from the light trough .7729 gram. Those from the dark according to this determination weighed 16.47 per cent more than those from the light. This weighing gives a smaller average difference than the last estimate.

No weight determinations were made between April 7 and May 20. On the latter date 307 fish were taken from the dark trough and 208 from the light. Both groups were preserved in formalin and after two days they were dried as uniformly as possible and weighed. Table 12 gives

TABLE 12.	*Comparison of weights of fish taken May 20*

Group	No. of fish	Total weight in grams	Average weight in grams
Fish from dark	307	475.040	1.5474
Fish from light	208	270.626	1.3010
Difference in average weights ..			.2464

the results of this determination. Comparing the average weights, one finds the fish from the dark were 18.94 per cent greater than those from the light.

Twenty-eight fish were, picked at random from each of the groups taken May 20. Measurements of their length and greatest depth were made. Tables 13 gives the maximum and minimum dimensions between

TABLE 13.	*A comparison of the dimensions of 28 fish from each group in table* 12

Group	Length in mm. varied between	Average in mm.	Depth in mm. varied between	Average in mm.
Fish from dark	43 and 53.5	45.36	9 and 12.5	10.99
Fish from light	36 and 50	42.44	8 and 12	9.61
Difference in averages		2.92		1.38

which they varied, also the average for each group. An increasing difference in dimensions between the two groups of fish is noticeable. The twenty largest and the twenty smallest fish were picked from each group and weighed with the following results:

> The 20 largest from dark weighed	...... 11.010 grams
> The 20 smallest from dark weighed ...... 22.320 grams
> The 20 largest from light weighed ...... 38.360 grams
> The 20 smallest from light weighed ...... 14.210 grams

The 20 largest from the dark trough weighed 83.7 per cent more than the 20 smallest from the same trough, while the 20 largest from the light trough weighed 169.4 per cent more than the 20 smallest from the same

trough.   Again a comparison of the 20 largest from each trough and the
20 smallest from each trough showed that while the 20 largest from the
dark trough were only 6.9 per cent heavier than the 20 largest from the
light, the 20 smallest from the dark trough were 56.7 per cent heavier
than the 20 smallest from the light.   Not only, then, was the difference
in weight between the two groups increasing, but those in the light were
developing much more irregularly than those in the dark.

Another comparison was made between the two groups on June 15.
The results are given in table 14.   The average weight of those from the
dark was 23.26 per cent greater than that of those from the light.

TABLE 14.   *A comparison of the weights of fish taken June 15*

Group	No. of fish	Total weight in grams	Average weight in grams
Fish from dark	179	329.980	1.8434
Fish from light	171	255.740	1.4955
Difference in average weights..			.3479

From each of these groups the 12 largest and 12 smallest were taken
and their weights were:

> The 12 largest from dark weighed   ...... 31.480 grams
> The 12 smallest from dark weighed ...... 15.790 grams
> The 12 largest from light weighed ...... 28.420 grams
> The 12 smallest from light weighed ...... 11.700 grams

The weight of the 12 largest from the dark was 99.36 per cent greater
than that of the 12 smallest from the same group, and the 12 largest from
the light weighed 142.91 per cent more than the 12 smallest from the
light.   A comparison of the 12 largest and 12 smallest from each group
showed that the 12 largest from the dark were 10.76 per cent heavier
than the 12 largest from the light, and the 12 smallest from the dark
were 34.95 per cent heavier than the 12 smallest from the light.   This
determination does not indicate quite such an irregularity in growth as
the preceding estimate.

Shortly after the last determination the fish were taken from the
troughs in which they had been kept up to this time and placed in artificial
feeding ponds similar in design to those in plate 18.   These feeding ponds
were 4½ feet in diameter and 17 inches deep.   Water was admitted
through pipes (a) turned in such a direction as to cause the water to flow
in a spiral to the outlet pipes (b) in the center.   The top of this pipe
was 10 inches above the bottom of the pond, and screens (c) prevented
the escape of the fish through the outlet pipes.   The pond A was painted
white, and a 60-watt tungsten light was placed above it and kept it con-
stantly lighted.   The pond B was painted black, and covered so that very
little light was able to enter it.
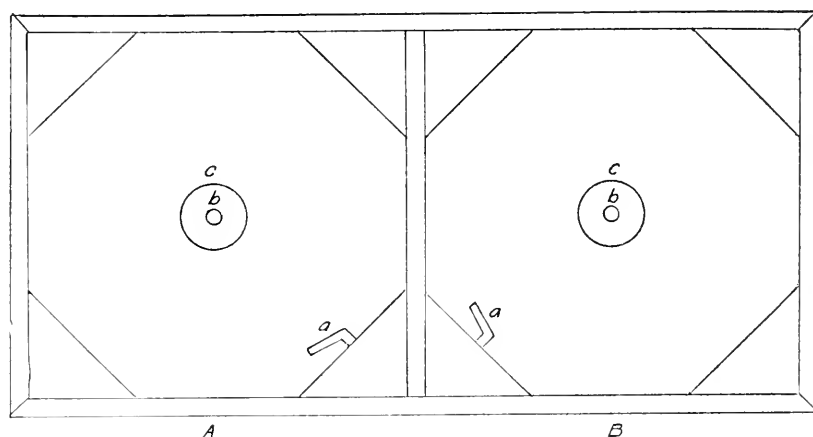
PLATE 18

Diagram of feeding ponds; A, B, the two ponds; a, water inlets; b, water outlets; c, screens.

The last comparison of the fish was made September 17. The fish were taken as at other times by a random sweep of the net and carefully dried on a linen towel. Table 15 gives the relative weight. In this comparison the fish from the dark weighed on the average 40.73 per cent more than those from the light.

TABLE 15. *A comparison of the weights of fish taken Sept.* 17

Group	No. of fish	Total weight in grams	Average weight in grams
Fish from dark	73	424.760	5.8186
Fish from light	158	653.280	4.1346
Difference in average weights ..			1.6840

The 12 largest and the 12 smallest were selected from each group and weighed with the following results:

The 12 largest from dark weighed ...... 106.980 grams
The 12 smallest from dark weighed...... 23.740 grams
The 12 largest from light weighed ...... 81.610 grams
The 12 smallest from light weighed...... 16.320 grams

The variation in growth had increased remarkably, the 12 largest from the dark being 350.63 per cent heavier than the 12 smallest, while the 12 largest from the light were 400.06 per cent heavier than the 12 smallest.

The extreme variation in growth is shown by the weights and measurements of the largest and smallest fish from each of these groups. Table 16 gives these determinations. The length in all cases was measured from the tip of the snout to the base of the middle ray of the caudal fin. The largest fish from the dark was but little less than eight times as heavy

as the smallest from the dark, while the largest from the light was nearly nineteen times as heavy as the smallest from the light.

TABLE 16.   *Comparison of weights of largest and smallest fish from each group taken Sept. 17*

Group	LARGEST		SMALLEST	
	Weight in grams	Length in mm.	Weight in grams	Length in mm.
Fish from dark	13.420	97	1.700	47
Fish from light	17.670	107	.950	42

Record of Mortality

A record of the mortality was kept from the time of hatching, on November 15, to the end of March.   During this period 263 dead were removed from the darkened trough and 293 from the trough kept in the light.   Since there were approximately 4,520 fish in the dark trough and 3,800 in the light, there was therefore a mortality of 5.82 per cent among the fish kept in the dark and 7.71 per cent among those kept in the light.

Another point of practical importance is that it required much less work to keep the dark troughs clean than it did those exposed to the light. This was due to the fact that the light favored the growth of the low plant organisms.

Observations on Humpback Salmon

A study of the comparative development of the young of the humpback salmon (*Oncorhynchus gorbuscha*) was made under similar conditions to those under which the young of the king salmon were studied. This was done with a view to checking upon the latter.   These eggs were a part of a shipment made by the United States Bureau of Fisheries from Afognak, Alaska, to a hatchery at Birdsview, Wash.   About 2,000 of these eggs were sent from Birdsview to the University of Washington by parcel post, arriving November 24, 1914.   Their temperature at the time they were received was 17°C., which was gradually reduced to 12°C., and then they were placed in the water of the troughs having a temperature of 10.5°C.   The eggs were later divided into groups, one of which was placed in the dark trough and completely covered from the light, and the other was placed in a white trough exposed to the light of day, in addition to which a 60-watt tungsten electric light in a cup-shaped reflector was suspended within one foot of the surface of the water and kept lighted continuously.

The hatching period extended over a much longer period of time than that required by the kings.   This irregularity in hatching was largely due to the low temperature of the water.   It is also possible that the eggs

were not all spawned at the same time. These conditions would not de-
tract from the value of the experiment as the eggs were so thoroughly
mixed that both baskets would be equally affected. The fish began to
leave the shells within two days of the time the eggs arrived at the hatch-
ery on the campus. The separation into two groups did not take place
until November 29, at which time 12 fish were hatched. These 12 are
not counted in the table below. In table 17 is recorded the date on which

TABLE 17. *The rate of hatching of humpback salmon in darkness
and light*

Date	IN DARK TROUGH		IN LIGHT TROUGH		
	Hatched	Dead in egg	Hatched	Dead in egg	Temperature
Dec. 2	19	18	32	9	9.5
" 3	13		36		9
" 4	34		45		9
" 6	23	44	113	21	8.5
" 8	261		216		8.2
" 11	219	12	212	27	8
" 12	75		62		7.4
" 13	31		62		6.5
" 15	45	9	78	13	6
" 18	46		44		5.3
" 19	7		13		5.5
" 21	8		16		5
" 29	13	4	9	17	5
Totals ..	787	87	983	87	

the count was made, the number hatched between the times of counting,
the number of dead removed and the temperature of the water in degrees
centigrade.

The number in the dark trough was 874; the number in the light
one, 1,070. Table 17 shows that those in the light hatched more
quickly than those in the dark, at least during the early period of hatching.
During the first five days of hatching after December 1, 10.18 per cent of
the fish in the dark hatched out, while 21.12 per cent of those in the light
hatched out. Those in the light were observed to free themselves quickly
from the shells and pass through the wires of the basket to the bottom of
the trough; on the contrary, those in the dark showed no disposition to
escape quickly from their shells, and many of them were observed to be
lying quietly half in and half out of the shell. Soon after the baskets
were removed, which was done December 29, those in the light began to
struggle up stream and maintained a position as close as possible to the
upper end of their compartment; but those in the dark showed no dis-
position for some time to leave the bottom at the lower end of the trough,
where the water drifted them.

At the time of the closure of the yolk-sac slit a careful weighing was
'made of 114 fish from the light trough and 108 from the dark. These
fish were taken at random by a single sweep of the net from each trough.

As much water as possible was removed by wiping the under side of the wire gauze strainer in which they were caught. The results of this weighing are given in table 18. These figures show that the average weight of those kept in the dark was 9.97 per cent greater than those in the light.

TABLE 18.   *The weight of humpback salmon from darkeness and light at time of closure of yolk-slit*

Group	No. of fish	Total weight in grams	Average weight in grams
Fish from dark	108	28.460	.2635
Fish from light	114	27.320	.2396
Difference between average weights ...			.0239

After the yolk was absorbed the young humpbacks developed in a very irregular way. Many of them made almost no growth while others made very rapid growth, far exceeding that of the kings of the same age. By June the large ones began to eat the small ones. The mortality up to this time was very high both in the dark and in the light. The results were such that it seemed scarcely worth while to make further observations to determine the influence of darkness or light upon them.

Up to the time of complete yolk absorption the dark and light environment produced similar effects upon the humpbacks to those observed in the kings. They hatched more quickly in the light than in the dark, at least during the earlier part of the period; those in the light were decidedly more active than those in the dark; and at the time of complete yolk absorption those in the dark were considerably heavier than those in the light. The experiment on both king and humpback salmon is being repeated this year and up to the present time, December 28. 1915, the results confirm those recorded in this paper.

SUMMARY

1.   During the hatching period of young king salmon those kept in the light exhibited a restless activity not seen in those kept in the dark, as a result the former hatch out more quickly than the latter.

2.   After the fish were hatched, those in the light continued to exhibit a restlessness and activity not shown by those kept in the dark. Those in the light left the bottom of the trough and distributed themselves throughout the water much sooner than those retained in the dark. This activity on the part of those in the light caused them to absorb the yolk more quickly than did those in the dark, and at the same time the increased metabolism due to this increased activity resulted in a retardation of their growth, so that at the time of complete yolk absorption, the in-

active fish from the dark weighed 11.28 per cent more than the active ones from the light.

3.   Chemical analysis showed that, while water made the main difference in weight between the two groups of fish, the percentages of water, protein, fat and ash were nearly the same for the two groups.

4.   After feeding began, numerous determinations of relative weights showed that the fish in the dark continued to increase in weight over those kept in the light.   After eight months' feeding the fish from the dark trough weighed 40.73 per cent more than those from the light.

5.   The fish did not develop uniformly in either trough, but those retained in the dark, while averaging much more in weight than those from the light, were also much more uniform in size.

6.   The mortality among those kept in the light was nearly two per cent more than that among those kept in the dark.

7.   Observations upon humpback salmon kept under similar light conditions gave similar results.   Those in the light were more active, hatched out more quickly, at least at first, left the bottom of the trough earlier, absorbed the yolk more quickly, and at the time of complete yolk absorption were nearly ten per cent lighter in weight than those from the dark.

Codium mucronatum

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This paper is a morphological study of *Codium mucronatum*, the principal object being to establish those characteristics which distinguish it from other species, and those which form the basis for its varieties.

Codium mucronatum grows fairly commonly on the exposed rocky shores of Puget Sound, in the lower littoral and upper sublittoral zones. Muenscher (13) places it in the Ulva association. Plants are occasionally found growing alone on isolated rocks, but usually they are very abundant within a small radius. The gregarious habit and rather limited distribution would indicate either that the reproductive bodies are not carried far, or that conditions favorable for their growth are very definite. The plant body consists of a basal expanded portion, the so-called holdfast-cushion, and one or more cylindrical dichotomously branched fronds growing from it, erect when small, drooping when older (*Fig.* 1). The whole plant is spongy in texture and dark green in color. The surface is more or less rough, with a dull velvety appearance due to the protrusion of the tips of the utricles. The fronds reach a maximum height of 40 cm. and are from .4 to 1 cm. in diameter. The tips are blunt and rounded. The branching is not always truly dichotomous for the frond may divide into as many as five branches at one point. Several plants were found with the fronds fairly covered from base to tips with young branches coming out like large warts all over the surface. In some places these branches had reached a length of 1 cm. and resembled young fronds starting out at right angles to the old.

The holdfast-cushion averages 3 mm. in thickness and has been found covering an area of 100 sq. cm. In color and texture it is the same as the frond. Growth takes place outward from the edge, leaving the margin irregularly lobed. New fronds appear as small rounded knobs on the surface of this holdfast-cushion. No matter how large the older parts, new fronds continue to appear between the old fronds or around the edge, singly or in groups. The largest plant observed, one whose holdfast-cushion covered an area of 7.5x13 cm., consisted of 20 large fronds and at least 50 young ones in various stages.

From the knob-like stage the frond elongates and becomes a clavate stalk slightly constricted just back from the tip (*Fig.* 1). The young

frond may fork a centimeter from its base, or it may grow to a length
of 10 cm. before dividing. The distance between successive forkings of
the branches varies greatly in different plants, but the mature frond has
usually divided at least six times. Quite often, instead of forking, the
frond gives off smaller branches; or it may divide into three or more equal
parts. One frond was found which at the first forking divided into five
parts. Three of these were large and branched dichotomously thereafter,
and two were small and branched irregularly. This same tendency toward
trichotomous or polychotomous branching is noted by Ernst (7) in *C.
tomentosum.*

The frond and holdfast-cushion consists of continuous, branching,
hypha-like threads, referred to as pith-filaments; and club-shaped branches,
referred to as utricles, which extend perpendicularly to the surface and
constitute a compact cortex (*Fig.* 18). According to Berthold (2) the
germinating spore of *C. tomentosum* first produces a branching "rhizom"
from which grows a tuft of erect filaments of equal length. By the
"rhizom" he probably refers to the original horizontal filament of the
holdfast-cushion, and the tuft of erect filaments is evidently the begin-
ning of a frond. Oltmanns (14) describes the germination a little dif-
ferently: "Aus der Zygote resultiert.......... ein vertikaler Spross, der
mit lappiger Scheibe auf dem Substrat festsitzt. An der Basis desselben
.................brechen seitwärts dünne Fäden hervor, um recht bald
Blasen zu bilden, die ihrerseits wieder basal aussprossen." Küster (11)
describes in detail the formation of a frond. According to him each utricle
is originally the enlarged end of a pith-filament and so at first is growing
erect. It gradually turns from the vertical to a horizontal position ex-
tending at right angles to its former position. From the base a slender
branch which is a new pith-filament grows upward. This finally en-
larges at the end and in turn becomes a utricle which bends to a hori-
zontal position. Examination of frond tips of *C. mucronatum* shows this
same method of growth to prevail in this species (*Figs.* 15, 16, 17).
That utricles never originate as lateral branches has not been proved.
Young branches have been seen a considerable distance from the end
of the filament, but whether they are utricles or merely branches of the
pith-filament cannot be determined when they are very young (*Fig.* 20).

Pith-filaments are 28-40 μ in diameter, thin-walled and usually
colorless, though in some cases there is a limited amount of chlorophyll
specially in the holdfast-cushion. The filaments at the lower ends are
expanded to form a 3- to 4-lobed holdfast, which may be colorless, or filled
with chlorophyll (*Figs.* 3, 4, 5, 8). There is usually a plug, which
serves as a cross-wall, just above the holdfast, though the distance be-
tween the latter and the first plug varies considerably. The pith-filament

may branch just above the holdfast (*Fig.* 5) or at some distance from it (*Fig* 8). Thus the so-called holdfast-cushion is composed of the basal ends of pith-filaments of the fronds with their interwoven branches, and the erect utricles which constitute the compact surface layer. These utricles vary both in size and shape more than do those of the frond. None were found bearing gametangia.

Pith-filaments and utricles of the frond differ only in arrangement from these of the holdfast-cushion. The distance between two successive utricles on the same filament may be anywhere from a distance so short that the two utricles lie almost against each other, to as much as 6.5 mm. (*Figs.* 18, 19). One filament was found which, though broken off 10.2 mm. from the end, had no utricles branching from it, nor did it have the tip at all modified to form a utricle.

In the formation of a utricle the end of a pith-filament expands and the tip becomes very pointed. The points vary in length and acuteness from long tapering ones characteristic of young utricles at the base of the frond, to shorter more rounded ones at its tip. The point, or mucron, is gradually filled nearly solid by the deposition of layer after layer of material against the inside of the wall (*Fig.* 9). The utricle may still be growing erect on the end of the pith-filament (*Figs.* 15, 16), or it may already have bent at right angles, in which case it is growing horizontally toward the surface of the frond (*Fig.* 17). From the base one or more slender branches extend the pith-filament upward (*Figs.* 16, 17). Thus layer after layer of utricles pile themselves on top of each other at the tip of the frond and so increases its length. Young utricles are also found anywhere along the frond growing from branches of these same filaments.

The utricles cease elongating when they reach the surface of the frond. Mature utricles are .9-1.5 mm. long, and average 150-350 μ in diameter although one was measured that was 630 μ. They are club-shaped, tapering at the base, broad and truncate at the end (*Fig.* 23). There may be a slight constriction a short distance from the end or near the base; or there may be a considerable enlargement at or below the middle. The outer end is densely green with chlorophyll, and in the older utricles is often collapsed (*Fig.* 26).

Utricles do not branch as Oltmanns (14) describes and pictures them for *C. tomentosum*, but occasionally one is found with another utricle growing from its outer end (*Figs.* 2, 6, 37). In one case, two smaller utricles were seen originating one from either side of the mucron of the main utricle (*Fig.* 33). Such irregular branching is more common in the holdfast-cushion than in the frond; and structures such as those shown in

Figs. 2, 6, and 7, though rather typical of the former, are rare in the fronds.

Old utricles are different from young ones not only in size and shape but in the nature of the mucron. The youngest utricles have no real mucron, but have a pointed tip shaped like a mucron with only a thin wall around it (*Fig.* 10). Utricles a little older can be found with the very end solid, and the process of filling up the tip to form a mucron indicated by the presence of layers of the substance not yet laid down tightly against the preceding layers. This often results in what Svedelius (18) calls "das Gegliedertsein des Mucro," in which case there is a row of compartments extending clear to the tip (*Fig.* 9). Sometimes the mucron is solid in which case it usually appears striated, faint lines indicating the layers composing it. The older truncate utricles push up around the mucron as the end expands and broadens so that the mucronate tip appears shorter and less conspicuous. Contact with wave action, rock surfaces, and investing animals, all of which would contribute to the wearing off of the originally long mucron, account in part for the fact that the mature utricles have short, often rounded mucrons, and sometimes none at all (*Figs.* 24, 40). This variation in the size and shape of utricle and mucron is shown by a series of sketches in Fig. 24.

Although one would suppose that the greatest number of young utricles are found at the tip of the frond, on every plant examined the greater number of slender, tapering long mucronated utricles were at the very base of the frond, this type sometimes predominating for a distance of 6 cm. up from the base. The average size of utricles increased as parts nearer the tip were examined, the largest ones being above the center of the frond and continuing large up to within 2 cm. of the tip. The average dropped very suddenly from there to the end, where the utricles were of course all very small. To bring out these facts more clearly measurements of utricles were made at various points along the frond. A large number from each point were measured and the average size computed. These averages for the same relative points on the different plants were in turn averaged to give the following results. The average diameter at the base of the frond was 105 μ; 2 cm. from the base, 151 μ; 4 cm., 168 μ; 6 cm., 189 μ; 12 cm., 220 μ; 14 cm., 312 μ; 16 cm., 357 μ. This largest size predominates to within 2 cm. of the tip where a perceptible decrease in the average begins.

The slender utricles at the base of the frond were next examined to determine if they were small because they were young, or because they were physiologically different from those of the upper part of the frond which bear the gametangia. In most cases it was very evident that they were young, i.e., terminal. Therefore the time when these plants were

studied must have been a period of rapid growth, when large numbers
of new pith-filaments were starting up from the holdfast-cushion. One
would expect that these filaments would have to push out between the
very oldest ones of the preceding crop. The fact that none of the very
large utricles were found at or near the base must mean that the utricles
of the lower part of the frond never grow large; this must indicate that
they are physiologically different, probably without the power to re-
produce, since gametangia were never found on the lower part of the
frond.

The fact that the mucronate tips of the basal utricles appear marked-
ly different from those of the young utricles of the same size at the tip
confirms the supposition that they are really different. The character-
istic mucron of the base is longer, often more acute, and more distinctly
striated than the common form at the tip (*Fig.* 9). The latter rarely ex-
ceed 30 μ in length (*Fig.* 14), while mucrons 70 μ long and more are
common at the base. The longest of these basal ones measured was 250 μ
long. The basal ones are very often oddly thickened and misshapen in
plants on which the mucrons of the rest of the frond are all normal (*Fig.*
11). Then, too, utricles of the base often have enormously thickened
walls at the end, not found in any other part of the plant (*Figs.* 12, 13).
Also the basal utricles differ in shape from those of the same size above.
The former are more tapering at the end than the latter, and thus appear
more slender than the young ones of the same diameter at the tip. It is
improbable that the difference in the pressure to which the utricles are
subjected could cause such wide variations.

An interesting feature of the genus *Codium* is the so-called plugs
which serve as cross-walls to divide the pith-filaments into compartments.
Although similar structures are found in other genera of this family,
notably *Bryopsis* and *Dichotomosiphon,* they differ from those of *Codium*
in several essential respects (7). Those of *Codium* are not of the same
composition as those of the other genera, and completely close the tube
of the filament when mature.

Plugs occur very frequently throughout the entire plant. When a
young pith-filament starts up from the base of a utricle, a plug develops
just above its origin from the latter, so that a plug always occurs in a
filament near a utricle, almost invariably just above it (*Figs.* 17, 18, 23).
They may also appear at irregular intervals anywhere along a pith-fila-
ment, and one is usually present near a branch (*Fig.* 19). Rarely there
is a plug in the base of a utricle. There is always one at the base of a
gametangium and often at the base of a utricle hair (*Figs.* 28, 44).

Plugs evidently function as cross-walls. They hold the cell con-
tents in place and thus prevent the loss of a whole filament when an in-

jury occurs to some part of it. The necessity for cross-partitions of some
sort in a plant which grows erect at least in part, and which is composed
of filaments many inches in length, is every evident. They keep the cell
contents evenly distributed and in their proper place. As evidence of this
function it may be said that chloroplasts are often seen piled up against
one side of the plug while there are none on the other side. Plugs sep-
arate the contents of gametangia and utricle hairs and prevent an opening
into the plant when these organs are broken off. Ernst (7) and Küster
(11) make a point of the fact that two plugs, one on either side of a
utricle in the pith-filament, cut it off entirely from the rest of the filament.
This is not true in *C. mucronatum* for there is ordinarily but one plug in
the filament near the base of the utricle, and that is just above its origin
(*Figs.* 17, 18, 23). This plug appears while the young pith-filament grow-
ing up from the base of the utricle is still very short.

The plug is formed by the deposition of successive layers of sub-
stance on the inner wall of the filament so that it often appears striated,
the lamellæ extending in the direction of the filament. An oil immersion
lens will sometimes show layers not yet tightly appressed to the pre-
ceding ones, leaving spaces between successive layers (*Fig.* 48). Fig. 49
shows the beginning of new layers. There is a striking similarity between
the method of formation of the plug and the mucron. Then, too, the sub-
stance laid down is apparently the same, judging from the fact that ru-
thenium red produced the same reaction in both. Up to the time that
plugs are mature a narrow opening is left between compartments of the
filament, and by pressing on the cover glass, chloroplasts may be made to
pass through it (*Fig.* 48). The mature plug completely fills the filament
for a distance of 30-45 μ (*Fig.* 47).

Characteristic of many plants of *C. mucronatum* are the utricle hairs.
—short slender branches, originating near the end of the utricle. Küster
(11) describes them in *C. tomentosum* as trichome tubes, but the one he pic-
tures is different in shape from those of *C. mucronatum,* being thicker,
broader at the base, and approaching more nearly the shape of the gamet-
angium of the latter species. Not all plants possess these structures,
and even in a plant on which they are fairly common they are not present
on every utricle. It has been reported (12) that when *C. tomentosum*
is grown under artificial conditions the utricle hairs branch extensively and
sometimes become similar to the utricle in shape.

The young hairs first appear as rounded projections of the wall of
the utricle 180-255 μ from its tip (*Fig.* 25). In two-thirds of the speci-
mens measured this distance was almost exactly 225 μ. As many as six
hairs may be found on one utricle but very often there is only one. In the
former case they may not be all of the same size, some a few μ's in

length while some may be as much as 500 μ. The diameter is uniform except where it tapers slightly at the base, and is about 30 μ in mature hairs. The hairs are usually colorless, but often look granular (*Figs.* 26-32).

Utricle hairs sometimes break off evenly just above the plug which is usually present in the base, thus leaving smooth scars (*Fig.* 27), or they may shrivel up without dropping off (*Figs.* 43, 44). Küster (11) says that in *C. tomentosum* the plug in the base is 1-sided with an open canal into the utricle, the canal remaining open until the hair breaks off. In *C. mucronatum* this plug is not 1-sided, nor does the canal always remain open in maturity. Küster mentions the possibility of determining the age of a utricle by the number of scars present, since new hairs grow in a new spot when old ones break off. This is referred to by Oltmanns (14) as the periodicity of the utricle hairs. The only evidence bearing on this point obtained in the short time that the plants were under investigation by the writer was the fact mentioned above that the hairs on any one utricle are usually of different sizes pointing to the possibility that they do appear successively (*Fig.* 26).

The function of the utricle hairs has not been definitely determined. They were found on young and old plants, and on utricles bearing gametangia (*Figs.* 43, 44); but it may be significant that many plants on which the hairs occurred very frequently, had no gametangia. One plant was found with hairs longer than on the others, and in this plant they were present on a larger number of utricles. Curiously, with few exceptions, there was only one hair on a utricle. Whether such variations in size and occurrence are due to differences of environment was not determined. Harvey (9) described the utricles of *C. tomentosum* as "clothed with hyaline, soft, byssoid hairs which when expanded in water stand out vertically and give to the branches the tomentose character." Their comparative rarity and colorless appearance in *C. mucronatum* suggest functionless degenerate organs.

Falkenberg (8) thought that the utricle hairs in *C. tomentosum* and *C. elongatum* were degenerate gametangia, sometimes developing in place of the latter. It is true that on some plants examined by the writer gametangia were wanting and the hairs unusually common: but the latter originated nearer the tip of the utricle at a level above that at which gametangia arise. This indicates a real difference in the two. Further, it is not uncommon to find both gametangia and utricle hairs on the same plant, and sometimes on the same utricle.

Berthold (3) considered the utricle hairs of *C. tomentosum* a protection against intense light. He said that their development was directly related to the intensity of the light; that on shaded parts of the

plant or on plants growing in poorly lighted places, the hairs were rudimentary or lacking, while on exposed parts, specially in spring and summer, they were enormously developed.   Küster (11), however, does not agree with Berthold on this point.   The writer did not find during this investigation that *Codium mucronatum* grew any more commonly or any differently in shaded places than in well lighted ones.

The numerous hairs found in *C. tomentosum* may be simply a protection against unfavorable conditions.   Those in *C. mucronatum* would then be degenerate protective organs, for they are too few in number to be of any use in this capacity.   A comparison of the development of utricle hairs of plants in protected habitats with those exposed to violent beating by waves might throw some light upon their cause or utility.   Küster (11) reports that near Rovigno, where he made his observations, those species of *Codium* provided with utricle hairs were free from epiphytes, both plant and animal; while *C. bursa* was so overgrown with *Ectocarpus, Sphacelaria* and sponges that in many cases the surface of the plant was completely hidden.

Küster (11) reports hairs 1 cm. long in *C. tomentosum*.   He says that they are not functionless but are storehouses for photosynthetic products; that since the hair remains in communication with the utricle this food is available during the winter and is valuable when the plant is reproducing.   This could hardly be the case when the plug in the base of the hair is solid, as is often found to be true in *C. mucronatum*.   Ernst (7) has the same idea as to the function of the hairs—"Ein Teil der Assimilationsstärke wird aus den grünen Fäden durch die Protoplasmaströmung in die rhizoidenartigen. zum Teil als Reservestoffbehälter funktionierenden chlorophyllosen Fäden geführt, in welchen in Leukoplasten die Neubildung von Reservestärke aus gelösten Kohlenhydraten erfolgen kann."

The majority of writers on *Codium* describe sexual reproduction by means of large green female gametes and small yellow male gametes, both biciliate.   During the present investigation in which many different plants all reproducing abundantly were carefully examined, only one kind of gametangium was found.   This on account of its large size and dark green gametes was the female gametangium if this species is heterogamous.   These gametangia are ovate lateral branches which originate just above the middle point of the utricle (*Fig.* 41).   They are 250-450 μ long and 75-150 μ in diameter.   Saunders (15) says that the gametangia of this species "arise from near the base of the peripheral filaments." Svedelius (18) indicates the same location in a figure.   In no case did the writer find gametangia near the base of the utricles.

The beginning of a gametangium is a protrusion of the wall of the

utricle like the beginning of a utricle hair (*Fig.* 34). The young gametangium is very blunt and rounded at the tip (*Fig.* 38). As it grows older it may become more tapering (*Fig.* 39), or remain broad at the end (*Fig.* 35). Chlorophyll collects in it until it is densely green. A plug develops in the base, cutting it off completely from the utricle (*Figs.* 38-42). The contents round up into a large number of bright green gametes 12-16 μ in diameter, which contain distinct chloroplasts (*Fig.* 46). The gametangium often contains a considerable number of oil globules. The gametes escape from it by means of the splitting of the tip into two "flaps," one of which is usually seen folded back (*Fig.* 45). The inside of the gametangium as seen through this opening appears very rough with wart-like protruberances. There may be one, two, or rarely three gametangia on a single utricle, all usually originating at the same level (*Figs.* 40-42), but occasionally one will be above or below the others (*Fig.* 39).

The reproducing area of a *Codium* plant may extend from the tip to within one or two inches of the base; but gametangia are most abundant within two inches of the tip. In the great majority of plants examined, gametangia were found no nearer than .5 to 1 cm. from the tip; but in several cases they were found at the very end. Fig. 38 shows a very young utricle, still terminal, with an almost mature gametangium. Two plants were found with no gametangia within 1.25 cm. of the tip. Very few plants were found not reproducing, some of those only 6 cm. in height bearing abundant gametangia.

The possibility of parthenogenetic germination of these large gametes is suggested by the failure of all efforts to find the small male gametes supposedly present in this genus. Either these appear at a different period, or they are very rare, or entirely wanting. The former alternative is improbable since no plants were seen which gave evidence of having borne male gametangia or of being about to do so. Collins (4) says that "it is probable that female zoospores of *Codium* sometimes germinate parthenogenetically." Thuret (19) reported direct germination of "zoospores" of *C. tomentosum.* Hauck (10) describes "Zoosporangien." Berthold (2), however, could not get any germination until plants with the larger gametes were grown with those bearing different, smaller gametes. Collins (4), Wille (21), and Ernst (7), ascribe both kinds of gametes to the whole *Codium* genus. Svedelius (18) reported two kinds of gametangia on specimens of *C. mucronatum* from Tierra del Fuego and West Patagonia. He says that the female gametangia are shorter and broader than the others. Oddly enough, he pictures only female gametangia and female gametes in spite of the fact that the male organs had never been pictured nor adequately described. The only convincing account of the

occurrence and fusion of unlike gametes is given for *C. tomentosum* by Oltmanns (14). He says "Schon Berthold hatte gezeigt, dass nur dann Keimpflanzen von *Codium* zu erhalten sind, wenn man männliche und weibliche Exemplare zusammen kultiviert. Ich habe dann im September 1896 die Kopulation in der beistehend skizzierten Weise, die einer weiteren Erörterung kaum bedarf, beobachtet." Went (20) suggests partheno-genesis in *Codium* but Oltmanns says this has not been proved.

Küster (11) describes a form of asexual reproduction that he found in *C. tomentosum*. It is simply the rounding up of the contents of a utricle when it has been injured, to form bodies, either colorless or filled with chlorophyll, which are expelled into the water by internal pressure, and grow into new plants. This was not observed by the writer in *C. mucronatum*.

The chemical composition of walls, plugs, and mucrons of *Codium* has not been definitely determined. Previous writers (6, 7, 11) have spoken of the "cellulose" plugs. However, no indication of cellulose in either plugs, mucrons or walls could be obtained with the standard cellulose tests,—iodine with sulphuric acid, and ammoniacal cupric oxide. Sometimes ruthenium red, specially in a rather concentrated solution, produced a deep pink color in the plugs and mucrons, which probably indicates the presence of a pectin compound. The color did not show in the walls, which may mean that they are of different material, or that they are too thin to show a color readily.

Dixon (5) found a structure in the utricle of *C. tomentosum* which he calls an axial strand. He describes it as a central column of a different refractive material in the center of the utricle, which has a club or funnel-shaped head. Structures fitting this description were seen in some preserved material of *C. mucronatum;* but owing to the fact tha the material had been preserved in formalin, it was not certain that they were natural. They were not seen in fresh material.

The distinguishing feature of this species of the genus *Codium* is the mucronate tip of the utricle. Various writers have divided this species into three varieties distinguished by the size, shape, and presence or absence of the mucron. Extended observation has shown that such differences alone are not sufficient to split this species into varieties; and unless there are other differences not mentioned in the descriptions, the division into three forms is not justified, for every type of mucron described may often be found on a single plant of *C. mucronatum,* the variations depending on the location of the utricle on the plant, differences being explained in part by the age of the utricle and the amount of weathering it has undergone.

Collins (4) gives the following account of *Codium mucronatum*:

"Codium mucronatum, J. G. Agardh, 1886, p. 43. Frond cylindrical, more or less regularly dichotomously fastigiate, surface more or less roughish; utricles cylindric-clavate, 5-10 diam. long, terminating in a distinct mucro.

"As described by Agardh, this species is divided between three varieties, with no definite typical form; it seems to take a place in the Pacific the same as that occupied by *C. tomentosum* in the Atlantic, and it is probable that most, if not all reports of the latter from the Pacific really refer to this species.

"Var. *Californicum* J. G. Agardh, 1886, p. 44, pl. 1, fig. 3; P. B. A. No. 229. Utricles in younger parts of the frond cylinderical, ending in a very acute mucro; in the older parts clavate, with a blunter mucro. Fig. 144. Alaska to Mexico.

"Var. Novae Zelandiae J. G. Agardh, 1886, p. 44. Utricles in younger parts subcylindrical, with a short mucro; in older parts clavate, mucro wanting or very inconspicuous. Vancouver. New Zealand.

"In var. *Californicum* the mucronate utricles are so well developed that the surface of the frond appears, even to the naked eye, not so smooth as that of *C. tomentosum*. In var. *Novae Zelandiae* they are much less noticeable, and some care is required to distinguish this variety from *C. tomentosum*."

Setchell (17) states that specimens from Sitka, Alaska; from San Juan Harbor (Port Renfrew), Strait of Juan de Fuca, Vancouver Island, B. C.; and from Whidby Island, Port Townsend, and Ludlow Bay, Washington, are *Codium mucronatum f. Californicum* J. Agardh; continuing, he says that "in all probability are to be included here, the specimens referred to *C. tomentosum* as follows: Norfolk Sound (Sitka Sound) and Nootka Sound, Turner (1811, p. 135, under *Fucus tomentosus*); Esquimalt, B. C., Harvey (1862, p. 176)." For *Codium mucronatum f. Novae Zelandiae,* he gives a specimen collected by Miss Butler and Miss Polley at Port Renfrew, B. C., and makes the following observations: "A careful study of *C. mucronatum* will probably show a very decided variation in the size and occurrence of the mucronate tip of the utricle. In the plants included under the preceding form, all studied by us have the typical tip of the *f. Californicum*. In the plant quoted under the present form, the mucronate tip to the utricle is to be found only in the very young portions of the frond. Below in the older portions, the utricles are more or less swollen at the tip, as in *C. Muelleri* Kützing, and while some of them show a very slight apiculus, the majority of them do not. The plant certainly differs from the more usual form on the Pacific coast of North America."

In view of the fact that young utricles may be found with either a long, acute mucron or a short one, on the same plant; and that in older

parts, the mucrons are either short and acute, or rounded, or absent entirely; it must be concluded that the above descriptions do not establish two varieties. For example, two plants were found which upon superficial examination revealed only utricles without mucrons. It was concluded that a variety different from *C. mucronatum Californicum* had indeed been found, but further examination of all parts of the frond proved it to be the same variety for the youngest utricles had the conspicuous typical mucron. Another specimen, in the herbarium of the Puget Sound Marine Station, determined by N. L. Gardner as *C. mucronatum Californicum,* if classified according to Collins, would fall under f. *Novae Zelandiae,* for only very short mucrons or none at all were found on the utricles.

The similarity between the utricles of the older parts of the fronds of *C. mucronatum* and those of the mucronless *C. tomentosum* is perhaps the chief cause of the common confusion of the two. A specimen of the latter species from Algiers, secured through the kindness of Dr. G. W. Farlow of Harvard University, was examined in various parts to see if it really differed from *C. mucronatum.* No mucrons were found on any of the utricles either young or old, proving it to be indeed different. Falkenberg (8) says that the characteristics of *C. tomentosum* fail to separate it from *C. elongatum.* It is interesting to note in this connection that Svedelius (18) reports it impossible to distinguish between *C. mucronatum Californicum* and the third variety, named by Agardh (1) *C. mucronatum tasmanicum* on the basis of a supposedly different type of mucron.

This study leads the writer to suggest the following description for *C. mucronatum* J. G. Ag.:

Plant body dark green, consisting of cylindrical, dichotomously branched fronds growing from a horizontal, irregularly expanded holdfast-cushion; both fronds and holdfast-cushion consisting of continuous, branching and interwoven, hypha-like, pith-filaments, from which club-shaped branches (utricles) each originally terminating a pith-filament extend perpendicularly to the surface, forming a compact cortex; individual filaments expanded at the base to form holdfasts; utricles clavate-cylindrical, .15-.35 mm. in diameter, .9-1.5 mm. in length, usually with thick-walled, mucronate tips; plugs functioning as cross-walls dividing the pith-filaments into compartments and separating the gametangia and sometimes the utricle hairs from the utricle; utricle hairs sometimes present; large green female (?) gametes 13-16 μ in diameter, borne in ovate gametangia 75-150 μ in diameter and 250-450 μ in length; 1-3 gametangia arising just above middle point of each reproducing utricle.

DISTRIBUTION—New Zealand, *Collins* (4); Straits of Magellan, West Patagonia, *Svedelius* (18); Sitka, Alaska, *J. G. Agardh* (1) and *De A.*

Saunders (16); San Juan Harbor. Strait of Juan de Fuca. Vancouver Island. B. C.. *Tilden* (17); San Juan Island, *Muenscher* (13); "under *C. tomentosum*," Whidby Island. Port Townsend. Ludlow Bay, Wash.. *Gardner* (17.); Sitka to the California Coast. *Saunders* (15).

SUMMARY

1.   The plant adheres to the substratum by means of a large number of holdfasts which are the expanded bases of pith-filaments. These, together with horizontal branches of the filaments and their utricles, constitute the holdfast-cushion.

2.   Utricles of the holdfast-cushion vary in size and shape more than do those of the frond. and do not bear gametangia.

3.   Normally the utricles of this species do not branch.

4.   The mucron is originally the thin-walled pointed tip of the utricle, which is gradually filled solid by the deposition of successive layers of material on the inside.

5.   The layers composing the mucron are often not tightly appressed to the preceding layers so that there is a row of compartments extending to the tip in an otherwise solid mucron. In shorter mucrons, the formation by layers is often indicated only by faint striations.

6.   Plugs, like mucrons. are formed by the decomposition of successive layers of material on the inside of the filament. They completely close the tube and so serve to keep the easily flowing contents of the plant more evenly distributed.

7.   There is only one plug near the base of each utricle in the pith-filaments, and that on the upper side of the utricle; instead of two. one on either side of the origin of the utricle, as commonly described for *C. tomentosum.*

8.   Utricle hairs are found only occasionally. usually 1-4 on a utricle.

9.   Utricle hairs may appear on the same utricle with a gametangium although some mature plants were found on which utricle hairs were unusually common and gametangia were wanting.

10.   The failure of all efforts to find male gametes suggests parthenogenesis.

11.   Gametangia are most abundant within two inches of the tips of the fronds. and are not found at the base.

12.   Walls, plugs and mucrons are not cellulose, and may contain pectin.

13.   Utricles at the base of the frond are more slender and with longer mucrons than those of the upper part.

14.   The facts that basal utricles are not only of different size and shape, with longer mucrons than those above, and often have oddly thickened and distorted end walls; and that they were not found with gametangia; suggests that they are physiologically different from the reproducing utricles of the upper part of the frond.

15.   The splitting of *C. mucronatum* into two varieties, *Californicum* and *Novae Zelandiae* distinguished by differences in the mucronate tips of the utricles is not justified, for all the described types may often be found on the same plant, variations being due to the age of the utricle, its location on the plant and the amount of weathering it has undergone.

I wish to express my appreciation of the assistance of Prof. Josephine E. Tilden under whose direction this investigation was carried on; and my gratitude to Dr. T. C. Frye, Director of the Puget Sound Marine Station, for many helpful suggestions.

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PLATE 19

1.   Habit sketch of young and old fronds. $\times \frac{1}{2}$.

2.   A terminal utricle from the holdfast-cushion with a second utricle growing at the end. $\times 75$.

3-5.   Top views of holdfasts. $\times 75$.

6.   Utricle of the holdfast-cushion with a second utricle growing from the end, and a pith-filament branching from the side. $\times 75$.

7.   Elongated utricles of the holdfast-cushion; plugs in various stages of development. $\times 75$.

8.   Pith-filament with plugs; holdfast at base. $\times 75$.

A. M. Hurd, Del.   PLATE 19

PLATE 20

9.   Mucron of a young utricle showing typical depositions of material forming it. $\times 625$.

10.   Tip of young utricle before mucron is deposited in it. $\times 75$.

11-13.   Utricles sometimes characteristic of basal portions of fronds. $\times 75$.

14.   Tip of young utricle showing the mucron which is characteristic of those at the end of frond. $\times 75$.

15.   Young utricle terminating a pith-filament. $\times 75$.

16.   Utricle turning to a horizontal position with young pith-filament starting from base. $\times 75$.

17.   Utricle with two pith-filaments growing from its base; formation of plugs. $\times 75$.

18.   Upper end of a pith-filament showing stages in the development of the utricle from the young terminal one to the mature utricle, and the location of plugs. $\times 75$.

10   11   12   13   14

9

17

15   16

18
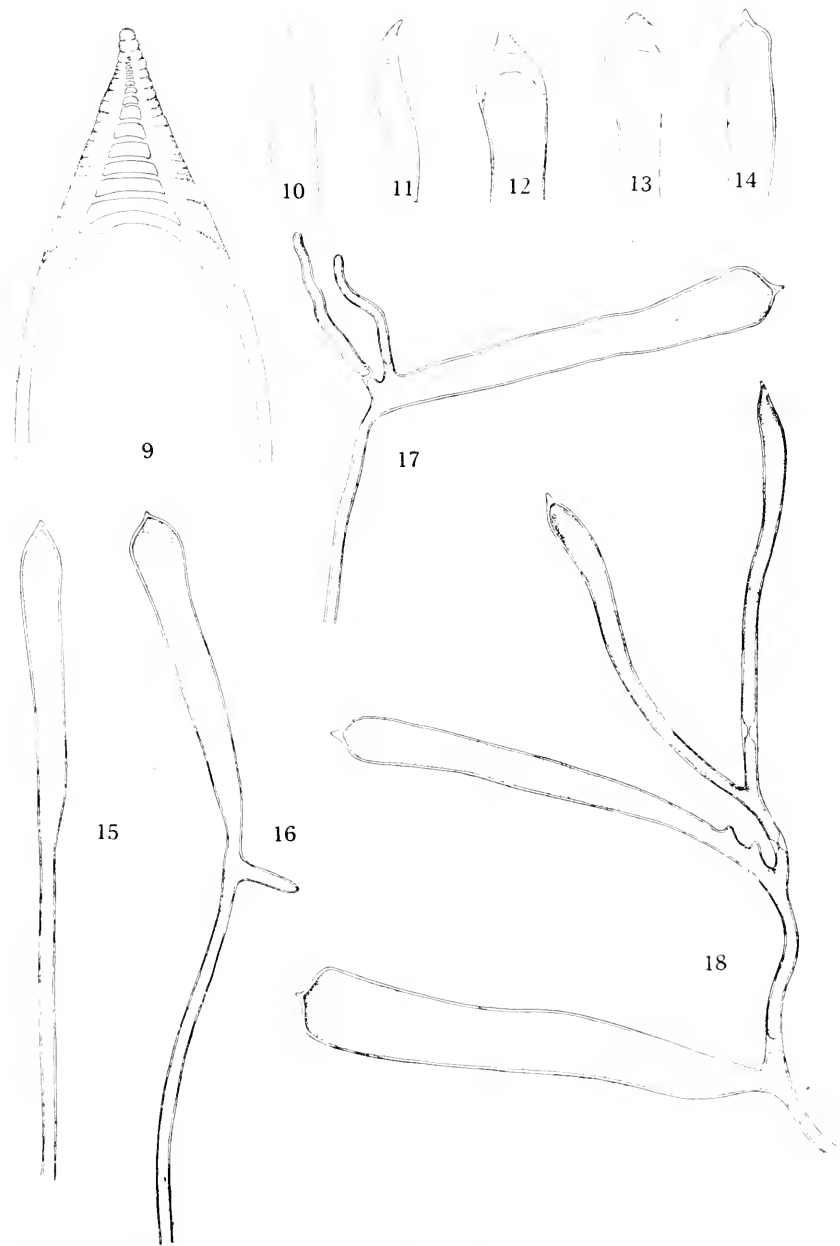
A. M. Hurd, Del.   PLATE 20

PLATE 21

19. Pith-filament; (a) characteristic ending of a frond filament. $\times 75$.

20. Upper end of a pith-filament. $\times 75$.

21. Utricle with unusual attachment; the result of a number of pith-filaments growing up from the base. $\times 75$.

22. Terminal and adjacent utricles. $\times 75$.

23. Typical utricle branching from a filament with plug near base on upper side. $\times 75$.

19

20

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22

23

a
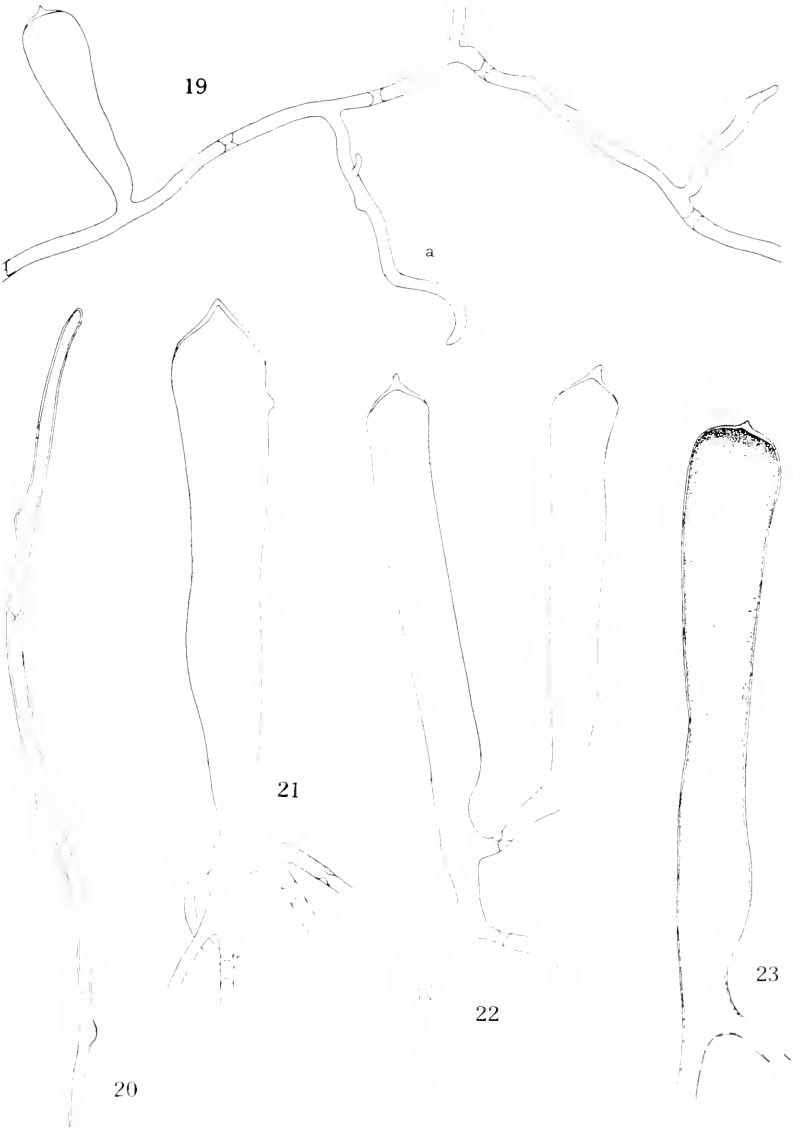
PLATE 22

24. Various mucronate tips of utricles on the same plant; *a*, young utricle; *b, c, d*, intermediate forms; *e*, oldest stage.   ×75.

25. Utricle with utricle hairs appearing.   ×75.

26. Old utricle with collapsed tip; utricle hairs.   ×75.

27. Utricle with scars of utricle hairs.   ×75.

28. Utricle with single long utricle hair with plug in the base.   ×75.

29. Utricle hairs in various stages on the same utricle.   ×75.

30. Typical utricle with young utricle hair.   ×75.

31. Type of utricle frequently found, with young utricle hairs (?) appearing.   ×75.

32. Utricle with utricle hairs.   ×75.
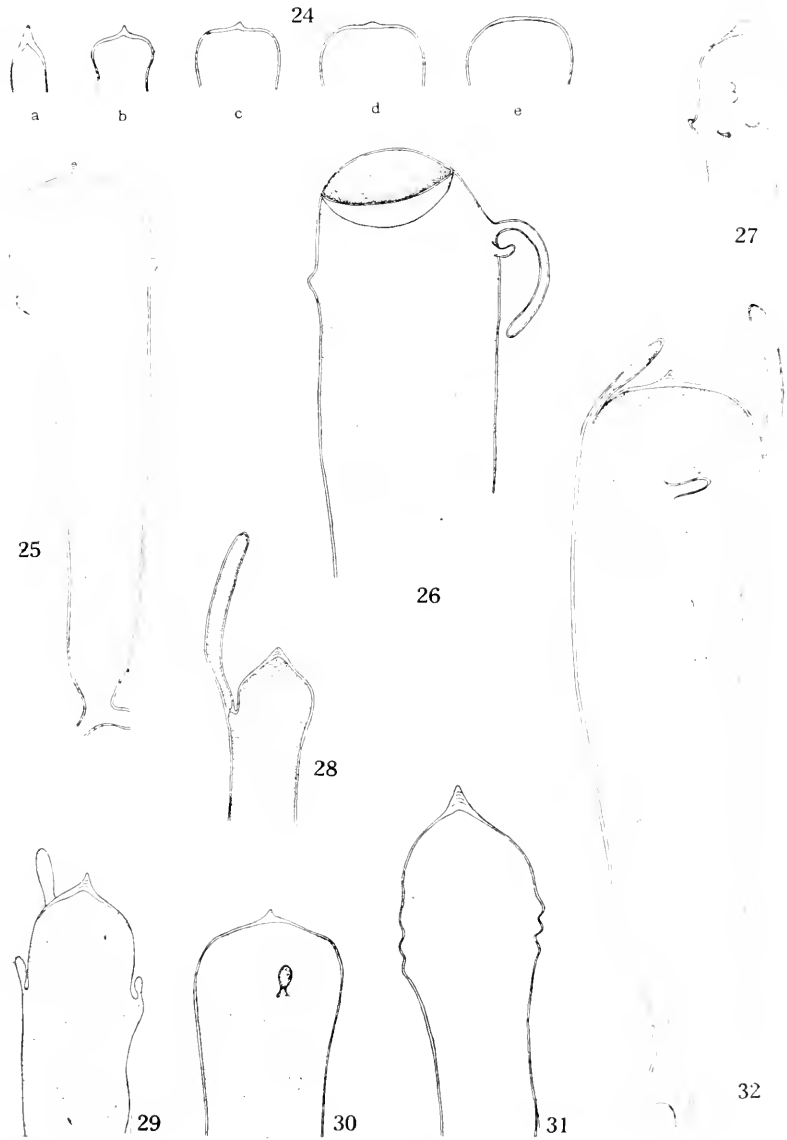
PLATE 23

33. Frond-utricle forked at the end. $\times$ 75.

54. Utricle with young gametangia appearing. $\times$ 75.

35. Young utricle, still terminal, with gametangium. $\times$ 75.

36. Terminal utricle with long mucron, and adjacent older one with short mucron. $\times$ 75.

37. Frond-utricle with a younger one growing from the end. $\times$ 75.

38. Utricle with young gametangium. $\times$ 75.

39. Utricle bearing three gametangia in various stages of development, not all on the same level. $\times$ 75.

40. Utricle bearing a mature gametangium with contents rounded up, mature plug in the base, and tip opening. $\times$ 75.

33

35

36

34

37   38   39   40

PLATE 24

41. Typical utricle with two gametangia, one containing gametes. ×75.

42. Typical utricle with three gametangia, one immature. ×75.

43. Old utricle with gametangium, utricle hair, and a scar of a hair. ×75.

44. Typical utricle with a gametangium, and with withered utricle-hair, and a second hair growing below it. ×75.

45. Tip of a gametangium showing opening. ×325.

46. Gametangium with mature gametes. ×325.

47. A mature plug. ×325.

48. Plug nearly mature, just closing the filament. ×325.

49. Plug just beginning to form, showing layers in process of formation. ×325.

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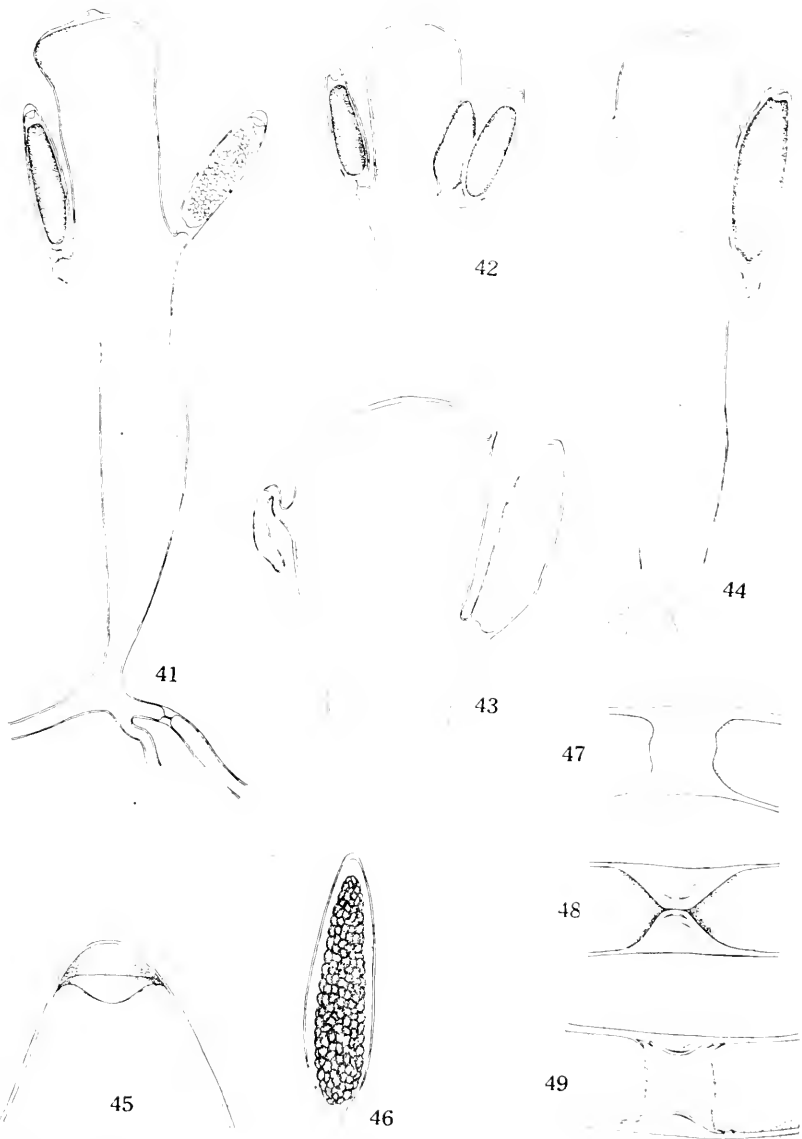
A. M. Hurd, Del.　　　　　　PLATE 24

Growth in Some Laminariaceae

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In a previous paper the writer (1) gave the results of observations on the growth of the blades of *Nereocystis*. This paper is the result chiefly of the extension of those observations to other members of the *Laminariaceae.* The work was done during the summer of 1915 at the Puget Sound Marine Station at Friday Harbor, Washington. Observations were made on the growth of the blades in length and breadth, elongation of the stipes, and any peculiarities of growth of either stipes or blades. Experiments were carried on with nearly two hundred plants of *Laminaria saccharina* (L.) Lam., *Laminaria bullata* Kjell., *Costaria costata* (Turn.) Saund., *Agarum fimbriatum* Harv., *Cymathere triplicata* (P. & R.) J. Ag., *Egregia mensiesii* (Turn.) Areseh., *Nereocystis luetkeana* (Mert.) P. & R. and *Alaria cordata* Tild.

Very little literature bearing directly on the growth of the kelps has come under the observation of the writer. Setchell (2) in his work on regeneration among kelps distinguishes three form of regeneration, viz. continuous physiological, periodic, restorative. His statements and figures are, however, entirely the result of observation on plants as he found them. He states that in all cases noted the regeneration proceeds only from the stipe, that in no case did restorative regeneration originate in the blade. In another paper Setchell (3) also refers to the increase in length of the blade at the base at the same time that the stipe is increasing at the upper end. Olga Müller (4) says the region of growth of *Laminaria* is at the point where the stipe joins the blade. Ramaley (5) states that the growing region of *Egregia* is situated at the base of the blade, and that the blade grows but very little after the stipe has attained a length of one meter. In this paper Ramaley (5) homologizes the parts of *Egregia menziesii* with those of other members of the *Laminariaceae.* Referring to *Egregia* he says: "Both rachis and lamina increase in length but the lamina commonly attains a length of only 3 to 5 dm., while the rachis may become very long. Some plants collected in the month of July were 6 to 8 meters in length." Yendo (6) discusses growth in length of *Costaria, Undaria,* and *Laminaria,* giving the general regions of greatest growth.

Experience with *Nereocystis* led the writer to believe that most of the work might be done from a raft. To test this plants of *Costaria* and of

Laminaria 5, 10, 20, 40, and 60 cm. long were located in their natural
habitat and marked. Three plants of each species were selected of each
length. Their growth was compared with the growth of the same num-
ber, kind and length of plants artificially attached to a raft. The figures
thus secured of the growth in length of the 15 naturally attached *Costaria*
plants showed an average daily increase of 1.264 cm., while 15 plants
artificially attached to the raft showed 1.226 cm. The average daily in-
crease of the 15 naturally attached *Laminaria* plants was 1.08 cm., while
that of the 15 artificially attached to the raft was 1.094 cm. No more vari-
ation was shown between those naturally and artificially attached than
between different plants of either group. The averages in each case show
a slight increase in the plants attached to the raft over those naturally
attached. Therefore, for the convenience of the experimenter, a raft
about 5x14 feet was constructed of logs with boards on top. The plants
were tied by means of cloth strings to staples driven into the logs on the
sides. Each individual plant was numbered on the raft near the staple.
In a great many cases small stones aided in submerging the plants to any
desired depth by varying the length of the strings. A record of the growth
of the plants was kept between June 15th and August 6th. The measur-
ing was done with a celluloid millimeter ruler. The plants were marked
with slight, straight cuts or scratches made with the point of a knife down
the center of the blade, or on the midrib of those species which possess
one. As the blades grew, the marks also broadened and lengthened, but
could easily be discerned from scars made by *Lacunae* or other animal
pests of attachment; except in those plants experimented with to see what
effect the removal would have, and others from which they had been torn
accidentally in the course of the experiments. The tables given in this
paper represent not the growth of a single plant, but the average of several
plants.

Comparing the results obtained from the growth of plants from which
the holdfasts and a large part of the stipes were removed with those from
which the holdfasts had not been removed, shows that the plants grow as
well without the holdfasts or even a large part of the stipes as with them.
The average daily increase in length of several *Costaria* plants with the
holdfast present was 1.5 cm.; others without the holdfast, 1.4 cm. The
average daily increase in length of several *Alaria* plants with the holdfast
present was 2.01 cm.; of others of about the same length without the hold-
fast, 2.04 cm. The same indifference to holdfasts obtains in the other
genera of plants experimented with, although the figures are not given.

The effect of removing the tips of the blades proved to be equally
negligible. Plants of the same approximate size grew nearly at the same
rate even tho the tips of some were removed. Mature plants, however,

grew faster than young ones, likely because the growing region is longer.
Cutting off the tip apparently did not materially effect the growth so
long as the basal 5-50 cm. of the blade was left (*table* 1.)

TABLE 1.   *Showing the growth of plants cut to different lengths.*

Number of days of growth	Original length of stipe	Original length of blade	Final length of stipe	Final length of blade	Increase in length of stipe	Increase in length of blade
Costaria	cm.	cm.	cm.	cm.	cm.	cm.
18	21	5	23.0	9.5	2.	4.5
18	16	10	16.3	28.1	.3	18.1
18	12.2	20	12.5	49.7	.3	29.7
18	17.5	40	17.9	72.7	.4	32.7
18	12.5	50	12.9	81.6	.4	31.6
Laminaria	cm.	cm.	cm.	cm.	cm.	cm.
38	1.6	5	1.8	55.9	.2	50.9
38	4.2	10	4.5	63.9	.3	53.9
38	5.0	20	5.3	122.6	.3	102.6
38	7.	40	7.5	82.1	.5	42.1
Alaria	cm.	cm.	cm.	cm.	cm.	cm.
37	60.3	5	61.2	52.4	.9	47.4
37	56.3	10	57.4	65.2	1.1	5.2
37	19.0	20	21.0	89.9	2.0	69.9
37	28.0	40	29.8	126.3	1.8	86.3
37	40.0	80	41.3	200.1	1.3	120.1
37	69.0	110	70.4	311.7	1.4	201.7
Agarum	cm.	cm.	cm.	cm.	cm.	cm.
20	1.3	5	1.4	10.2	.1	5.2
20	2.5	10	2.5	16.3	.0	6.3
20	7	20	7.2	24.4	.2	4.4
20	4	30	4	36.1	.0	6.1
20	2.6	35	2.7	46.8	.1	11.8
Cymathere	cm.	cm.	cm.	cm.	cm.	cm.
28	5.0	5	5.2	5.5	.2	.5
28	5	10	5	16.9	.0	.9
28	4.7	20	5.1	27.0	. .	7.0
28	8	110	8.8	128.4	.8	18.1
28	8	190	8.4	212.9	.4	22.9

Not only will the plants grow when the holdfast is removed and the
stipe shortened, but even small portions of the growing region of the
blades will grow when cut out, tacked to a submerged raft, and held in
place by strips of cotton.   Other pieces too small to be kept secure by
such a method were tied up in a cheese cloth bag and submerged at the
side of the raft.   Even pieces as small as 1 mm. square, showed some
growth, and many of those slightly larger, more than doubled their length
in 10 days (*table* 2).   Each of these pieces was cut from the basal grow-
ing portion of the blade.   Other pieces corresponding in size cut from near
the tip of the same blades—as for example 100 cm. from the base in
Alaria—showed no increase in length or breadth.   Small pieces of *Cyma-
there* showed only a very slight growth even when selected from the base
of the blade.

The growth of the stipe is extremely slow compared with that of the

blade (*table* 1). In most plants no growth was found in it; in others, and especially in the younger plants, a slight increase in length was observed. However, most of the growth of the stipe occurs in that part nearest the blade. In some of the records the greater increase in the length of the upper centimeter of stipe may have been due in part to the inclusion of a portion of the blade, since the transition point is often not clearly marked. The growth of the stipe evidently occurs mostly during the young stages, so that little elongation takes place after the blades are well under way.

Considerable growth takes place at the transition point between blade and stipe, so that the blade appeared to be growing backward from the first mark made at its base (*Fig.* 2). This growth at the transition point was noted in all the *Alaria, Laminaria,* and *Egregia* plants, though it was not so marked in *Costaria, Agarum,* and *Cymathere.* This may be due to the fact that in the three last named genera there is a more abrupt passage from stipe to blade, thus the boundary could be more accurately located; while in the three first named the more gradual merging of stipe into blade made it difficult to know where to place the boundary mark. Thus what appeared to be a backward growth of the blade (*Figs.* 2, 4, 6) may have been the increase in length of a very short basal portion of the blade considered as a part of the stipe.

The growth in width of the blade was an object of experiment in *Costaria, Laminaria, Alaria,* and *Agarum.* Yendo (6) says that when a young *Costaria* plant has developed the five ribs it begins to increase its length at a considerable speed, the increase in breadth not remaining proportional to the increase in length. He thus finds that at the beginning of summer the growth in length seems practically to have ceased in the blades, while the increase in breadth continues and causes remarkably wide plants. The writer has data for the summer months only; but these show more rapid growth in length than in width of the blade.

Various methods of locating the region of greatest growth in width were tried. All showed the same general result. One of these methods was to cut a longitudinal strip from the central region of a blade and observe where the greatest enlargement in width took place. The results by this method lend themselves well to graphic representation (*Figs.* 7, 8; 9, 10; 11, 12; 13, 14). This region is surprisingly near the base in all the blade; and it practically coincides with the region of most rapid elongation. In those plants having a midrib it is necessary to leave a small strip of the thin portion of the blade on the midrib, altho this may be very little. The rib alone will not grow a new blade so far as the writer's observations went. However, pieces of blade as small as 1 mm. square will grow in width (*table* 2).

TABLE 2. *Showing ten days growth of small pieces of blades.*

	Original Size		Size 10th Day	
	Length	Width	Length	Width
	cm.	cm.	cm.	cm.
Nereocystis ...	.1	.1	.16	.15
	.5	.5	.6	.57
	.1	4.8	.2	5.1
	.5	4.5	1.1	4.8
	.5	1.0	.65	1.2
Alaria	.1	.1	.15	.15
	.5	.5	.75	.6
	.1	3.1	.3	4.2
	.5	3.1	2.0	4.4
	.5	1	.7	1.5
	10	1	16.2	2.4
	5	1	10.1	2.2
Laminaria	.1	.1	.15	.15
	.5	.5	.6	.6
	.1	.4	.35	4.5
	.5	4	.9	4.6
	.5	1	.8	1.3
	10	1.5	18.3	2.7
	2	2.5	7.7	3.3
	4	1.4	10	7
	1	1	3.3	2.5
Costaria	15	1	34	3
	10	1	28	1.7
Cymathere	15	1	15.2	1.1
	5	1	5.3	1.1

In general during the summer season the larger plants grow more rapidly than the smaller ones, as might be expected from the usual experience with higher plants. Considering the large as well as the small plants experimented with, the average daily rate of growth in width at the most rapidly widening point was in *Costaria* 4.3 mm., in *Laminaria* 1 mm., in *Alaria* 2.8 mm., in *Agarum* 2.3 mm. No good data for rate of growth in width were secured for *Cymathere* and *Egregia*, but their growth is much larger.

Experiments were made to determine both the region and the rate of elongation. The basal limit of elongation is near the transition point between stipe and blade. *Egregia*, whose blades grade gradually into the stipes, shows more growth in the stipe than do those species in which the transition is abrupt. The region of greatest growth is from 2 to 20 cm. from the bast of the blade in the kelps experimented with (*Figs.* 8, 4; 5, 6); on the average it is greatest between 3 and 7 cm. from the base, depending upon the age and the form of the blade. In all the plants observed the growth was greatest in the general region of greatest width (*Figs.* 15, 16). If the blade broadens gradually, the region of greatest growth is farther from the base than if the blade broadens abruptly (*Figs.* 15, 16). In larger and older plants the growth continues for a greater length, but the proportion of growing blade is about the same as in the younger plants. In no case was there any perceptible growth found near the tip of the blade. Yendo (6) says that "the growth in length, as well as in breadth is due at a certain period, to both apical and the stipo-frondal growth. The apical growth is gradually retarded, and finally ceases.

Erosion of the apex of the blade follows next." The rate of growth increases very rapidly from the base upward for a short distance, then decreases abruptly, then more slowly until at the end of the blade no growth at all is observed (*Figs.* 4, 6).

It was found that the place of maximum growth in *Egregia* was not even near the base of the strap-shaped branches, but near the ends of these branches where they broaden out into the wrinkled blades, and in the lower part of these blades. Apparently the rounded strap-shaped part corresponds to the stipe of the other kelps, while the flattened broader parts that gradually emerge from the former correspond to the blades (*Figs.* 16, 17). This confirms Ramaley's (5) view of homologies. In the upper portions of these blades of *Egregia*, where they are firmer and not so pliable, no growth occurs; just as in the upper portions of the blades of other *Laminariaceae* there is no apparent growth. In this species the transition between stipe and blade is very gradual. Three blades with some stipe attached were left to grow for 8 days with the following results:

Original 35 cm., became 41.5 cm., increasing 6.5 cm.
Original 65 cm., became 73.1 cm., increasing 8.1 cm.
Original 250 cm., became 281.7 cm., increasing 31.7 cm.

Two other *Egregia* plants were grown for 8 days. These had the blades and holdfasts cut off, and were therefore mere stipes. They showed the following:

Original 170 cm., became 177 cm., increasing 7 cm.
Original 460 cm., became 463 cm., increasing 3 cm.

Since the stipes grow so little it is evident that most of the growth is in the blades and perhaps in the stipes where they grade into them.

To show more exactly the region of elongation, kelps of various species were measured into spaces from the base of the blade up, and in *Egregia* from the base of the blade down also. These kelps were then permitted to grow from 11 to 41 days and the spaces measured. The results are given in table 3. That the growth is mostly near the stipe is very evident.

The rate of growth for the 6 species experimented with varied with the individual and the species. The average daily growth was as follows: *Laminaria*, 2.85 cm.; *Alaria*, 2.23 cm.; *Costaria*, 2.04 cm.; *Egregia*, .98 cm.; *Cymathere*, .81 cm.; *Agarum*, .58 cm. The results of the rate of growth obtained for *Agarum*, *Cymathere* and *Egregia* are very unsatisfactory, as the conditions of submergence, aeration, etc., were not the most favorable for these plants. The growth of *Cymathere* was very slow for a plant of its length. It is quite possible that its growth may have been slow even in its natural habitat, at that time of the year; or it may be that the rapid growth was earlier in the season; or possibly it is not an annual plant. One would suppose, however, that taking the plants from a depth of from

TABLE 3. *Showing the elongating region in various kelps.*

Successive cm. from base of blade	Length of same space in Laminaria after 31 days	Length of same spaces in Costaria after 11 days	Length of same spaces in Alaria after 41 days	Length of same spaces in Agarum after 30 days	Successive 10-cm. spaces	Length of same spaces in Cymathere after 28 days	Length of same spaces in Egregia after 14 days
5	5.0			5.4			
5	5.2	5.0	5.0	5.4			
5	5.2	5.4	5.2	5.4			
5	5.5	6.1	5.2	5.4			
5				5.4			
1	1.2	1.3	1.1	5.6			
1	1.2	1.4	1.1	5.6	10	10.0	
1	1.2	1.4	1.2	5.6	10	10.1	
1	1.3	1.6	1.2	5.6	10	10.1	
;	1.3	1.6	1.2	5.6	10	10.1	
1	1.3	1.7	1.3	6.5	10	10.1	
1	1.5	1.8	1.3	6.5	10	10.2	
1	1.5	1.8	1.4	6.5	10	10.2	
1	1.6	1.8	1.4	6.5	10	10.2	
1	1.8	2.1	1.4	6.5	10	10.2	
1	2.0	2.3	1.8	1.5	10	10.3	
1	2.3	2.6	1.8	1.6	10	10.4	
1	2.8	2.8	2.0	1.7	10	10.6	
'	3.6	3.2	2.3	1.9	10	10.7	
'	4.4	4.1	2.8	1.9	10	11.1	
'	5.6	4.4	3.4	2.0	10	11.5	
'	7.0	**5.0**	4.8	2.3	10	12.0	12.0
'	13.9	4.6	7.7	3.3	10	13.1	12.6
1	**20.3**	3.5	13.0	**4.6**	10	14.8	15.4
1	12.5	2.2	**59.0**	4.0	10	**17.1**	**18.5**

Base of Blade

					10		11.5
					10		11.0
					10		10.3
					10		10.2
					10		10.2

15 to 65 meters and expecting them to live much nearer the surface, where there is a difference in pressure, temperature, light and aeration, would surely affect their rate of growth. There was a marked increase in the growth of those plants suspended 4 meters below the surface of the water over those suspended .6 meter below. But the same general principles that apply to the growth in the other *Laminaria* type of plants apply to *Cymathere, Agarum,* and *Egregia,* though the rate of growth is much slower. The removal of the thin portion of the blade from the midrib does not affect the growth in length of the rib (*Figs.* 1, 2). But the expanded portion of the blade is not again formed unless some vestige of this is left on the midrib.

Some sporophylls of *Alaria* were traced from their beginning as mere knobs to expansions 16.8 cm. long. Their average daily elongation was 5.5 mm. Their rate of growth varied from 1 to 15 mm. daily, depending upon the size and development of the sporophyll. After attaining con-

siderable size, the more nearly the sporophylls reached the stage of mature zoospores, the slower the rate of growth, until when that stage was reached the growth ceased. When the tip of such a sporophyll contained no zoospores it became ragged and worn off. In connection with periodic regeneration in *Laminaria* Setchell (2) emphasized the passing of the whole plant into a state of rest at the time of fruiting. In the same paper he adds: "Other species of this group, particularly of *Laminaria*, show similar contrasts between the earlier vegetative stages and the fruiting ones. The latter show thicker, darker-colored fronds, and the fact that active growth has stopped, is shown by the ceasing of increase in length for the stipe and the actual shortening of the blade, since the erosion at the summit is no longer made good by an increase from below." The slow rate of growth in the spore-forming blades of all of the kelps was observed. For example, one plant of *Cymathere* in which mature gametes or zoospores were found, increased from 30 cm. to only 30.7 cm. from July 17 to Aug. 6. A maturing blade of *Laminaria* increased from 40 cm. to only 40.7 cm. from July 25 to Aug. 5. Again, a blade of *Agarum* with reproducing patches increased from 30 cm. to only 30.9 cm. between July 25th and August 6.

The daily study of the kelps during the eight weeks of observations, made it possible for the writer to pick out the healthy growing plants by their color and texture. It is with them just as it is with the leaves of a tree, the more recent growth being lighter in color, and softer and more delicate in texture. The tips of the blades, where there is very little or no growth, are darker and duller; that is, they lack that soft, almost transparent new look that the growing portions have. The blades with fruiting patches can also be easily distinguished by their slight difference in color. MacMillan (7) refers to the fruiting patches of *Nereocystis* as being very conspicuous on account of their slightly lighter color than the sterile tissue.

TABLE 4. *Showing the gain in cm. of length during 8 consecutive days and nights for 5 species of kelp.*

Nereocystis		Laminaria		Costaria		Alaria		Agarum	
Night	Day	Night	Day	Night	Day	Night	Day	Night	Day
cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.
.5	.8	.3	.5	.7	1.8	.5	.8	.1	.5
.9	1.2	.4	.8	.3	6.5	.9	1.2	.2	.3
.6	1.2	.3	.5	.6	1.2	.6	1.2	.1	.25
.6	1.3	.4	.9	.4	.85	.6	1.3	.1	.2
.4	1.35	.4	.8	.6	1.2	.4	1.35	.1	.3
.5	1.1	.3	.5	.3	1.3	.5	1.1	.05	.1
.4	.9	.3	.6	.4	1.3	.4	.9	.05	.1
.4	.85	.4	.7	.7	1.9	.4	.85	.0	.05

Observations showed that the growth during the day was almost double that at night. On eight consecutive days measurements were made

at 5:30 o'clock. night and morning, on *Nereocystis, Laminaria, Costaria, Alaria,* and *Agarum.* Observations were made on several plants of each genus. The results are given in table 4.

SUMMARY

1.   Kelps will grow suspended from a raft as well as in their natural habitat.

2.   The holdfast and stipe are not necessary for the growth of the blades; holdfasts merely serve to anchor the plants; stipes hold the blades in the proper position for growth.

3.   Cutting off the tips of blades does not stop their growth. The larger plants grow faster than the smaller.

4.   Summer growth in the stipes of kelps, with the exception of *Nereocystis,* is very slow.

5.   Growth in the stipes occurs in that part nearest the blade.

6.   Blades of the various kelps may be cut into squares as small as 1 mm. and each piece still grow independently.

7.   Blades of kelps grow in width when cut into narrow strips.

8.   The whip-like midrib of *Alaria* will grow in length when the thin part of the blade is removed from it.

9.   The basal limit of growth of all the kelps named in this paper, with the exception of *Nereocystis,* is close to the transition point between blade and stipe.

10.   The greatest growth occurs not at the transition point between blade and stipe. but near the base of the blade. This is usually 3-10 cm. from the base, depending upon the age and form of the plant.

11.   The greatest growth in length usually occurs in the general region of greatest width.

12.   The rate of growth increases rapidly for a short distance from the base. and then decreases more slowly toward the tips of the blades. at which point no growth occurs in an ordinary July plant.

13.   The sporophylls in *Alaria* grow at rather a rapid rate. decreasing as the stage of maturity is reached.

14.   Kelps grow more in the day time than at night. the rate of growth during the day being almost double that at night.

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PLATES

PLATE 25

Fig. 1. *Alaria costata* with thin portion of blade cut off leaving only midrib; marked into 5 cm. spaces.

Fig. 2. Same plant as figure 1 after 41 days, showing the distribution of growth.

Fig. 3. Diagram of basal 10 cm. of blade of young *Laminaria saccharina*.

Fig. 4. Diagram of the same blade as figures 3. after 30 days, showing the distribution of growth.

Fig. 5. Diagram of the basal 10 cm. of young blade of an *Alaria costata*.

Fig. 6. Diagram of the same blade as figure 5. after 30 days, showing the distribution of growth.
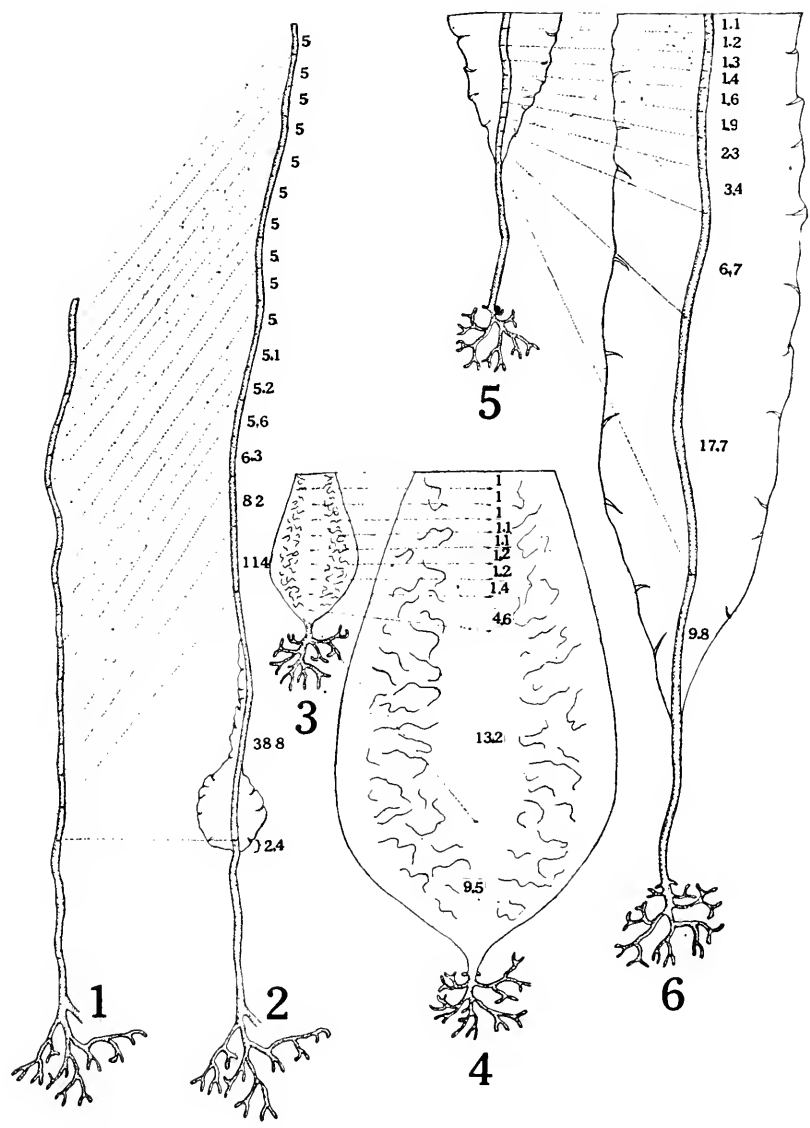
PLATE 26

Fig. 7.   Strip of *Alaria cordata* 20 cm. long marked into 5 cm. spaces; margin 5 cm. wide left on each side of midrib.

Fig. 8.   Same strip of *Alaria cordata* as in figure 7, 25 days later; from *m* to *s* is 4 cm.

Fig. 9.   Strip of *Costaria costata* 18 cm. long, marked into three 5 cm. and one 3 cm. spaces; margin 1 cm. wide each side of central rib.

Fig. 10.   Same strip of *Costaria costata* as in figure 9, 28 days later; from *s* to *r* is 13 cm.

Fig. 11.   Strip of *Agarum fimbriatum* 18 cm. long, marked into three 5 cm. and one 3 cm. spaces; margins 2 cm. wide each side of midrib.

Fig. 12.   Same strip of *Agarum fimbriatum* as in figure 11, 22 days later; from *s* to *r* is 9 cm.
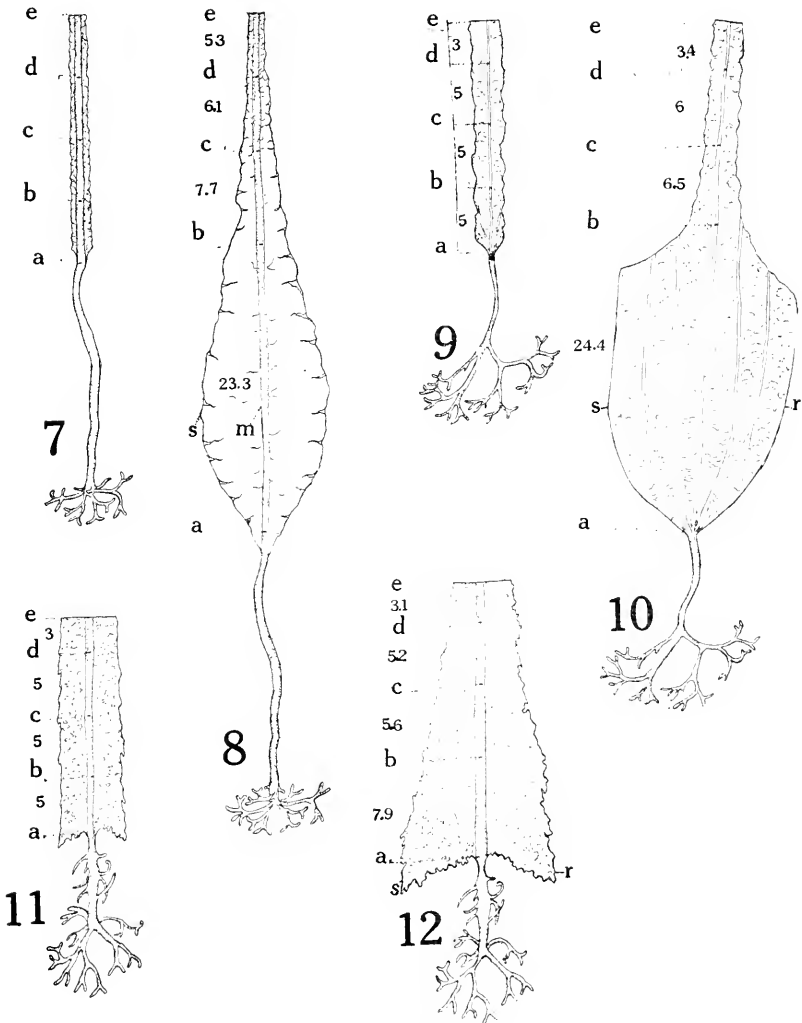
PLATE 27

Fig. 13.   A strip of *Laminaria saccharina* 30 cm. long and 3 cm. wide, marked into 5 cm. spaces.

Fig. 14.   Same strip as figure 13, 41 days later, showing distribution of growth.

5

5

5.2

5.6

9

5 3.1

3.4

14

13
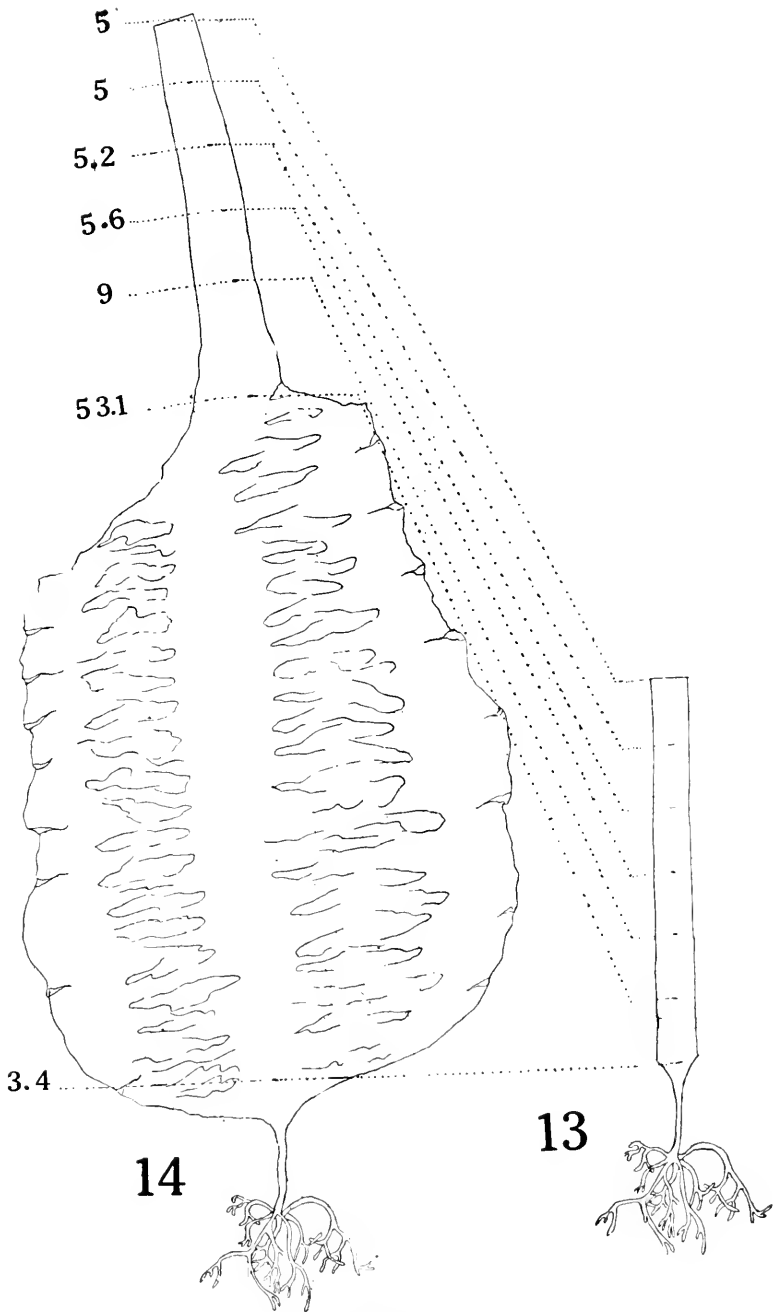
PLATE 28

Abbreviations.   *r*=frond. *f*=holdfast. *s*=stipe.

Fig. 15.   Diagrammatic sketch of *Laminaria saccharina* showing the region of greatest growth in a gradually broadening blade.

Fig. 16.   Diagrammatic sketch of *Laminaria saccharina* showing the region of greatest growth in an abruptly broadening blade.

Fig. 17.   *Egregia menziesii* showing which parts are homologous with those of *Laminaria saccharina* in figures 15 and 16.
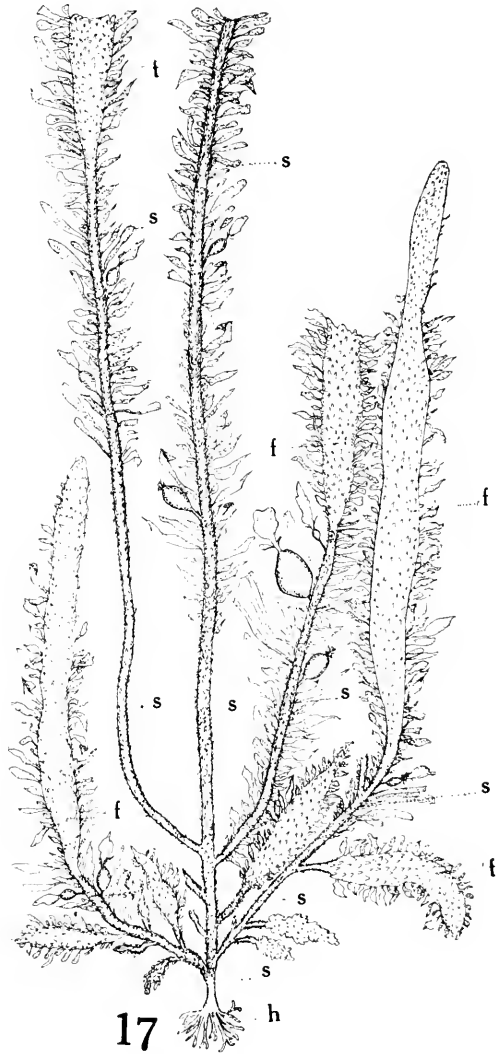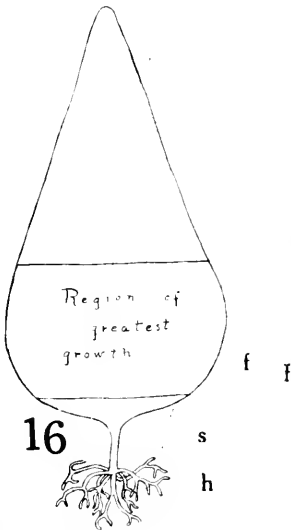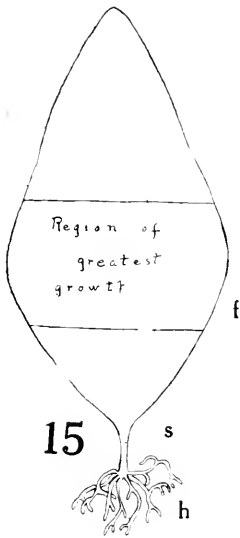
A. L. Fallis, Del.   PLATE 28

ERRATA—Vol. I, No. 14, Puget Sound Marine Station Publications

Page 162, line 4, for *included* read not included
Page 167, Table 5, line 2, for *all dead* read all alive; do. line 3 for *all alive* read all dead
Page 169, Table 7, read *Cancer oregonensis* opposite 2d line from bottom
Page 170, Table 8, read *recovered* line 10, in line 9

Physiological Differences between Marine Animals from Different Depths

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I. INTRODUCTION.

It has been the custom of students of distribution to assume that the physiological characters of individuals of a given species from different environmental conditions are essentially the same and that the *character of conditions* may be determined by a study of the presence or absence of different species. A most common type of work along this line is that of students of distribution on land, who decide that this or that factor controls distribution because a certain species is coincident with a uniform condition of the factor chosen. Further, of recent years the students of sanitary science have from time to time tried to use the occurrence of certain organisms as an index of contamination of water.

In view of these frequent apparent tacit assumptions that the physiological constitution of a species remains essentially the same throughout its range, it is a matter of utmost importance to know how far and to what extent it actually varies with difference in surrounding conditions. It is further of much importance from an ecological viewpoint that these subjects be thoroughly investigated. The physiological foundations of ecological work must be laid broad and deep and the question of correlation of the physiological characters of animals with surrounding environmental conditions. their variations in individuals of a given species. is a matter of utmost importance.

Physiological differences between animals of the same species from different environmental conditions has been investigated by Allee (1) who worked on isopods with striking results. Pond individuals show low percentage of positive rheotactic response while stream individuals show high positive response to the same current. The physiological agreement between animals of the same or similar communities and the physiological differences between different communities have been investigated by the writer (25).

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II. HABITATS, MATERIAL AND METHODS.

1. *General*

The Puget Sound Marine Station is located in a situation very fa-
vorable to the study of the problem at hand because of the diversity
not only of shallow water habitats, but of depth conditions. Within a
half mile from the station building it is possible to secure animals from
over 150 meters of water practically free from algae, which are a source
of difficulty in respiration work and various physiological operations.
There are also various kinds of habitats in shallow water. Bays of
varying degrees of exposure, with various sized bottom materials, rocks
exposed to the full sweep of the waves and rocks protected from severest
wave action. The greater part of the material studied was collected
from a definite area north of Brown Island, shown in the map (*plate* 29,
p. 174). Here the following belts may be recognized:

2. *Habitats*

The *Shore Belt* lies between high tide and average low tide. Mean
tide is nearly a meter below average low tide. The average low tide
is marked by the lower limit of such plants as *Fucus* and of shore
barnacles and by the upper limit of *Ulva*. It represents the belt usually
submerged and uncovered twice daily. On the shore of Brown Island
the shore belt represents about three meters vertical distance. The
shore is steep and covered with broken rocks. Depressions in the solid
rock often hold water which teems with small Littorina, purple shore
crabs, and sometimes small fish (*Oligocottus*). The water in these pools
often goes as high as $27°$ C. on sunny days. The rocks become quite
warm in the sunshine. Barnacles and limpets are sometimes fully ex-
posed to the sun. The incoming tide water often is $20°$ to $24°$ C. among
the warm rocks under which the shore crabs are numerous

The *Laminarian Belt* ($+1$ to $—20$ meters) reaches from average
low tide to the lower limit of the Laminariaceae. Most of the animals
appearing exposed at extreme low tides are distributed throughout this
belt. The broad leaved green algae afford shelter for many forms that
avoid exposure to the sun. The presence of these broad leaved algae
makes a striking contrast between the physical conditions of this kind
and all other belts. Tide and wave action keep the water well mixed,
and light penetrates to the bottom of this belt with a noteworthy decrease
in red rays only. Fol, the Swiss naturalist who worked in a diving suit
in the Mediterranean, found that at 10 meters light disappeared quite
suddenly early in the afternoon long before sunset. At 20 meters in
the Harbor of Funchal, Madeira Island, in June the Prince of Monaco

found that the day lasts 9 hours. It would be much shorter in the northern latitude in which Puget Sound is located. The reversing thermometer shows little differences in temperature between the surface and the bottom of this belt.

At other points than in the lower portions of this belt, red algae dominate and many of the animals are red. Fishes, shrimps, crabs and other invertebrates appear to have taken on the red color of the algae. Gamble (8) found that the young transparent stage of the European prawn, *Hippolyte varians,* takes on the color of its surroundings within 48 hours. If placed in green weed in full sunlight they become green; if placed in red weed they become red. Likewise to a lesser extent the shrimps, crabs and fishes of the green eelgrass are greenish. Gamble showed that fishes also tend to take on the color of their surroundings. The animals upon which Gamble experimented did not take on the color of the light to which they were exposed but took on the color of the background when exposed to sunlight.

The *Coralline Belt* (20-100 meters) is characterized by the absence of any form of algae of sufficient size to afford shelter. The water pressure ranges from 2-10 atmospheres. Wave action is not important but tidal currents may keep the bottom clean. The light throughout the belt is very weak. Fol found in his diving experiments in the Mediterranean that in 30 meters it was difficult to see animals,, specially red ones, which appear dark or black. Green or blue algae appear bright. The Prince of Monaco's experiments in the Madeiras showed that the day is short at these depths. At 40 meters light of daylight intensity was made evident by Regnard's (22) apparatus for only 15 minutes at about 2 P. M. Puget Sound being much farther north it is not to be expected that a day of more than a few minutes occurs. The lower limit of daylight must be approximately at the lower light of this belt. Our temperature measurements showed differences of a fraction of a centigrade degree. This belt is not very well defined. but since a number of species were not taken below 100 meters and a few were confined below this depth it was thought well to divide the Coralline belt of Forbes as suggested here. No material used in experiments was collected from this belt except in a narrow area studied by Miss Perry whose results are given at the end of this paper as Puget Sound Marine Sta. Pub. 1:175-176. 1916.

The *Sub-coralline Belt* (100-200 meters, no specimen taken below 165 meters) is a belt with water movement confined to tidal currents. There is probably no period during the day at which there is any light stronger than twilight. The upper limit is at about the deepest point at

which light sufficient to affect plates sensitized with silver chloride penetrates, while its lower limit is about the depth to which sufficient light penetrates to affect plates sensitized with silver iodobromide. The pressure ranges from 10-20 atmospheres. No material used in the experiments was obtained from this depth from any other locality than the narrow area studied by Miss Perry (*plate* 29).

3.   *Methods of Collecting and Keeping Material*

With the exception of specimens of three or four species obtained at stations A, B, C and D, the animals used in the experiments were dredged or secured between the tide lines in a small area north of Brown Island (*plate* 29). A regular Challenger dredge was commonly used; though at times a large Puget Sound trawl was used, especially where the bottom was known to be rocky. The Puget Sound trawl is apparently a local invention similar to the usual beam trawl but with a heavy iron bar from 1-4 inches from the level of the runners. The rig is not very effective and according to fishermen is being replaced by the usual type of beam trawl with a lead line instead of the bar.

Collecting was usually carried on in the forenoon, and experiments performed in the afternoon of the same day. Material from deep water was usually kept in a float car. The car had several compartments and was so constructed as to be towed out alongside the vessel. It was covered with a piece of heavy canvas. Several washtubs were also used and the water changed often. Material was kept in the float car until used. According to the experiments of Petersen (18), a dredge secures only about three or four percent of the animals on the surface over which it is dragged. They took some animals in the bottom sampler that did not appear in the dredging and vice-versa. Miss Perry's table at the end of this article shows the relative abundance of the animals obtained in the dredge but can not represent the true population of the bottom.

4.   *Water Supply*

The salt water supply of the station is pumped chiefly in the morning and evening from the bay immediately adjacent at about 4 feet below mean tide. It was stored in a wooden tank. The temperature rises from $11°$ to $14°$ C. on warm days. Differences in the character of the water from different points near the station were not wanting. Table 1 brings out some of these differences.

TABLE 1. *The dissolved gases of the sea water (from Shelford and Pow-ers) (24); data in cc. per liter.*

Col.No	Date	Place	Hour	Tide	Collected	CO_2	O_2	H_2S	Temp.
1	....	Point Caution	5:30 P. M.	Low, in	Surface	....	5.6	....	....
2	7-23	N. E. Brown Id.	10:10 A. M.	Low, out	Surface	1.76	4.9	.187	11.6
3	7-25	N. E. Brown Id.	11:10 A. M.	Low, out	Surface	1.64	4.6	.237	10.7
4	7-25	N. E. Brown Id.	7:15 P. M.	High	Surface	1.91	4.6	.268	10.5
5	7-26	S. Brown Island	10:45 A. M.	Low, in	8″ under Ulva	0.00	9.2	.536	16.5
6	7-23	S. Brown Island	12:00 M.	Low, in	8″ under Ulva	0.00	10.8	.536	13.2
7	7-25	S. Brown Island	12:00 M.	Low, in	18″ under Ulva	0.00	....	.339	13.2
8	7-25	Station dock	11:10 A. M.	Low, in	Surface	1.86	5.2	.149	11.6
9	7-25	Station dock	12:45 P. M.	Low, in	Surface	3.10	4.8	.205	....
10	7-26	Station dock	9:30 A. M.	High, out	Surface	1.81	4.2	.295	10.6
11	7-26	Tap, pumped at	6:30 A. M.	Med. low	4′ deep	1.76	4.7	.223	....

It is a matter of some surprise to find that there is a constant differ-ence in the water of the two sides of the harbor on which the station is located (compare lines 5, 6 and 7 with 8, 9 and 10). The south side is rocky at the point where the station is situated. Opposite it there is a sandy and gravelly bottomed shallow area with eel grass and much *Ulva.* The water on the south side is more acid at all times than the water on the north side. The water on the north side is usually neutral or slightly alkaline. At times, especially at the end of a sunny day, it is decidedly alkaline. The station being located on the rocky acid side has supplied water pumped usually in the evening and early morning and has never been satisfactory on account of the fact that animals do not develop well in acid water (14). Thus the eggs of most animals die in the tank water; this can easily be remedied by extending the intake pipe across the harbor.

The oxygen content of the water is higher on the north side of the harbor where there is an abundance of vegetation. It is often nearly twice saturation in this vegetation. On the south side of the harbor the oxygen content rarely reaches saturation. The sewage from the town of Friday Harbor and houses adjacent to the shore no doubt renders the water along the shore in front of the station more acid and reduces the oxygen content, but this influence can not be very pronounced on account of the continued stirring of the water by tide movement.

In addition to this, a series of oxygen determinations were made from which samples were collected by Miss Ione Trees in the eel grass across the harbor in front of the station over a little deeper water than

those of Shelford and Powers. These collections were made every 4 hours out of the 24. They showed a marked increase in CO_2 and a decrease in O_2 at midnight and at 4:30 A. M. Since the collections were not repeated the exact results are included here. Knudsen and Ostenfelt, according to Murray and Hjort (15), found that diatoms absorbed much O_2 in the dark; and with these operating in the same manner as the animals, such differences are to be expected.

5. *Methods of Experimentation*

The fresh water in 1915 came from Trout Lake, 8 miles from the station, the deep wells which supplied the town earlier having been abandoned. The lake is well supplied with fresh water animals and algae. In 1915 the end of the lake nearest the town had recently been dammed and some land covered with vegetation thus submerged. This led to considerable decomposition in the lake and in the pipes, the water reaching the station with a bad odor and no oxygen. An analysis showed the following:—Oxygen .00 cc. per liter; carbon dioxide, free, 15.7 cc. per liter, in carbonates 13.4 cc. per liter, in bicarbonates 13.4 cc. per liter; alkalinity 120 parts per million; chlorine 286.7 parts per million; hydrogen sulfide (iodine method) 0.51 cc. per liter. The water used was aerated and thereby the free carbon dioxide was reduced to 1-3 cc. per liter, the odor and hydrogen sulfide were removed, while the oxygen content rose to about 5 cc. per liter. The water thus became essentially as it was before leaving the lake. The fresh water experiments were conducted in this water held at the same temperature as the sea water by being immersed in a tank through which sea water flowed.

The temperature of the water from which the animals of the Laminarian and deeper belt were collected was about $11°$ C. The animals of the shore which sometimes are left in small standing pools may be subjected to as much as $24°$-$27°$ C. Animals from shallow water, especially those from eel grass, are subjected to temperatures somewhat higher than that of the other animals. All experiments were performed at $11.5°$-$13.0°$ C., which was the temperature of the running salt water.

Acidity was produced by adding enough hydrochloric acid $\left(\frac{n}{10}\right)$ to transform all carbonates to chlorides and give a small amount of free HCl. At the end of the experiment the water was titrated with $\left(\frac{n}{10}\right)$ sodium carbonate, methyl orange being used as an indicator. Alkalinity was produced by adding $\left(\frac{n}{10}\right)$ sodium carbonate, phenolphthalein being used as an indicator.

TABLE 2. *Showing the relative resistance of shrimps of the same and different species from differenth depths to high temperature.*
(P. Records by Miss Perry at Friday Harbor;
R. by Rathbun [21].)

Scientific and Common Name	Depth from which species is reported	Temperature	No. of Experiments	No. of individuals	Depth in meters from which taken	Survival time in minutes
Pandalus danae Stimp.	4-146 P.	24	3	14	4*	34
Coon-stripe Shrimp			3	15	14-20**	27
			2	2	40-60	21
			1	3	60-100	13
			1	2	100-165	12½
		25-26	1	1	40-60	20
.		30	1	5	****	¼
Pandalus stenolepis Rath.		19	1	1	****	*****
Deep Coon-stripe Shrimp	52-250 R.	24	1	1	40-100	11
	40-165 P.		1	1	100-140	8
			2	5	150-165	7
Paracrangon echinata Dana		24	1	1	40	37
Spiny Shrimp	25-96 R.		1	4	40-60	12
Spirontocaris lamellicornis Dana	18-130 R.	24	2	2	40-100	9
Crangon munita Dana	15-80 P.	24	2	6	40-80	14
Saddle-back Shrimp	22-105 R.	25-26	1	1	18-50	6½
Crangon alaskensis Lock	10-40 R.	24	1	10***	10	91
Frisco Shrimp	4-125 P.		1	1	40-50	5
		27±	1	3	40	211
			1	4	40-60*	155
Crangon communis Rath	25-600 R.	24	1	1	8******	2
Frisco Shrimp	8-150 P.		1	1	110-150	½
Pandalus borealis Kroy	60-700 R.	24	1	1	40-100	14
			1	2	100	8

*Green, from eelgrass, Station B.
**Red, from red algae, Station C.
***From Station A.
****Mixed.
*****Indefinite.
******A single specimen, from this depth, small, juvenile, on basis of size and age should have died first.

III. EXPERIMENTAL RESULTS

The experimental results are given in tables 2-8 where the essential data are arranged in condensed form. Only about two-thirds of the experiments are presented, but those not presented showed the same general results.

A.   Resistance to Temperature

The temperature experiments were performed in small dishes about 5 inches in diameter which were set into pans of sea water kept at the desired temperature by a small alcohol flame. The addition of warmer or colder water directly to the dishes was avoided where possible and great care taken to prevent the warmer water from coming into contact with the animal when it seemed best to add water of a different temperature. The temperature was maintained within a half degree of the stated temperature with little difficulty by simply watching it and manipulating the burner and water supply according to the needs.

In conducting such experiments much preliminary experimentation must be carried on to determine the temperature at which the animals die slowly enough to give good differential results, and at the same time die within a period in which it is possible to watch them. If the temperature is too high all animals may be killed at once, or if too low they may live for several hours, which makes absences necessary, rendering results unreliable, and causes much inconvenience.

In table 2 we find the specimens of the common coon-stripe shrimp from different depths die in different lengths of time, those from shallowest water living longest. The dying times are a series arranged inversely to the series of depths. An examination of the entire table shows that the same rule holds good for all the other species and for the different temperatures used. Further, when we compare the different species at the level of their greatest abundance (as indicated by the relative number of individuals experimented on) we find that the species most abundant at the greatest depths usually die quickest.

Turning to table 3 we find there is a similar difference in the species of crabs from the different depths. In a general way the crabs in the deeper water die quicker than those from the shallower water. *Cancer oregonensis,* however, when carefully collected from different depths does not show the differences indicated by the shrimps.

It is clear from the tables that there is a marked physiological difference between animals of the same and different species from different depths.

TABLE 3. *Showing the relative resistance of crabs from different depths
to high temperature. Compare depth at which taken and
from which commonly recorded with survival time*

Name	Depth from which recorded	Temperature	No. of experiments	No. of individuals	Depth from which obtained	Survival time in minutes	Habitat
Hemigrapsus nudus Dana... (Purple shore crab)	Shore 0–10 R.	24	1	2	0*	264	Often in sun
Lophopanopeus bellus Sti... (Black-clawed crab)	Shore	24	1	2	0*	264	Under stones
Petrolisthes eriomerus Sti... (Flat shore crab)	Shore	24	1	2	0*	264	Under stones
Cancer oregonensis Dana... (Cancer crab)	0–470 R.	24	1	2	40–50	264	Among stones
Scyra acutifrons Dana...... (Sharp-nosed crab)	0–40 R.	24	1	2	40–50	38	
Oregonia gracilis Dana..... (Decorator crab)	10–47 R.	24	1	2	?0	29	
Pugettia gracilis Dana...... (Graceful kelp crab)		24	2	2	15	14	In vegetation
Cancer oregonensis Dana...	0–470 R.	25–26	1	1	40–50	47	
Cancer oregonensis Dana...		25–26	1	1	80	47	
Cancer oregonensis Dana...		'5–26	1	1	110–150	47	
Hemigrapsus nudus Dana...		30	1	2	0*	190	High tide in sun
Lophopanopeus bellus Sti....		30	1	2	0*	17	Under stones
Petrolisthes eriomerus Stimp.		30	2	4	0*	17	Under stones
Cancer productus Rand.....		30	3	6	2–4	14	In vegetation
Cancer oregonensis Dana...	0–470 R.	30	2	4	40–50	13	
Telmessus cheiragonus Til..	0–40 R.	30	3	4	4	13	In vegetation
Oregonia gracilis Dana.....	10–270 R.	30	2	2	40–50	9	
Pugettia gracilis Dana.....	0–80 R.	30	2	7	14–20**	8	In vegetation

*Occurs above low tide.

**Red, from red algae; Station C.

B. *Relations to Fresh Water*

Fresh water experiments were conducted in small dishes surrounded
by running sea water which kept the temperature the same as sea water
used as controls. In the case of the animals put into the fresh water
the results were often very striking. Such animals as shrimps, which
stand in an upright position, fall over in from 2 to 15 seconds after being
placed in the fresh water and do not move extensively afterward. Move-
ment may be induced, for a considerable period, by pinching the abdomen,
but finally the movement of the gill bailer is all that can be detected.

Considering table 4, which is concerned with shrimps alone, we note that the shrimps of each species which were collected in shallowest water live longest in the fresh water. It will also be noted that the shrimps commonest in the shallower depths live for a longer time than those commonest in deeper water.

TABLE 4. *Showing the resistance of shrimps of the same and different species from differenth depths, to fresh water.*

Scientific Name and Common Name	Depth from which recorded......	No. of experiments......	No. of individuals........	Depth from which obtained, in meters......	Survival time, in minutes..
Pandalus danae Stimp................	4-146 P.	3	15	4-6	25
Coon-stripe shrimp		1	2	12-20	23
		1	1	30-50	13
Pandalus stenolepis Rath.............	52-250 R.	1	1	100-140	7
Deep coon-stripe shrimp	40-165 P.	1	5	135-165	7
Pandalus borealis Kroy.	60-700 R.	1	1	100-140	8
Pink shrimp					
Spirontocaris lamellicornis Dana......	18-130 R.	1	5	36-80	9
Crested shrimp				100	8
Spirontocaris polaris Sab.	20-425 R.	1	2	135-165	5
Red-ringed shrimp					
Crangon alaskensis Lock.	10-40 R.	4	24	14	85
Frisco shrimp		1	2	15-20	120
Crangon munita Dana	22-105 R.	1	2	15-20	54
Saddle-back shrimp	15-80 P.	10	10	35-75	24
Crangon communis Rath.	40-600 R.	3	3	90-140	10
Paracrangon echinata Dana	25-96 R.	3	5	40-100	25
Spiny shrimp		2	2	140-165	6

Experiments with crabs (*table* 5) showed results similar to those shown by the shrimps (*table* 4). The method employed in the work on crabs was slightly different as the crabs are more hardy but cease all noticeable activity in the fresh water and still often recover after being returned to the salt water. Thus as the table shows the crabs were put into the fresh water for the period recorded and then returned to the salt and the number dead and recovering noted as given.   In general

TABLE 5.   *Showing the resistance of crabs of the same and different species from different depths, to fresh water.*

Scientific and Common Name	Depth which cies is corded which spe- from re-	Depth which taken. from	No. of ments. experi-	No. of uals. individ-	Survival time, in minutes.	Condition end of posure at ex-
Hemigrapsus nudus Dana.. (Purple shore crab)	Shore to 10 R. +3-0 P.	Shore	1 1	5 3	960 157	2 dead All dead
Cancer productus Rand.... (Cancer crab)	0-20 P.	Shore	1	3	140	All alive
Telmessus cheiragonus Da.. (Helmet crab)	0-40 R.	5**	1	3	140	2 alive
Cancer oregonensis Dana.. (Small cancer crab)	0-470 R.	20-50	3	13	67	9 alive
Lophopanopeus bellus Sti. (Black-clawed crab)	0-	Shore	1	3	62	1 alive
Lophopanopeus bellus Sti. (Flat shore crab)	Shore	Shore Shore	1 3	3 9	62 60	All dead 2 alive
Scyra acutifrons Dana..... (Sharp-nosed crab)	0-40	40	1	3	35	All dead
		5	1	2	22	Dead
		40-60	1	1	22	Dead
Pugettia gracilis Dana.... (Graceful kelp crab)	0-80 R.	5*	3	12	62	4 alive
		15*	2	9	87	6 alive

*From Station D.
**From Station B.

it will be noted that the crabs from deeper water are less resistant.   The purple shore crab is most resistant and lives out of water at low tide.

Table 6 shows the other animals on which similar experiments were performed.   Here again the methods employed with the crabs w e used. Animals belonging to the same group showed the same general relations as in the other case.   The animals such as barnacles and mussels which close the shell in fresh water live for long periods.   The time given is the time which the animals were actually in fresh water, as it was neces- sary for them to be placed in the salt water for a time to determine their conditions.

C.   Resistance to Acidity and Alkalinity

By acidity we mean that the concentration of hydrogen ions is in excess of the concentration of hydroxyl ions; by alkalinity we mean the excess of hydroxyl ions over hydrogen ions.   Moore and Whitley (14) found that an addition of .0015 mol of caustic alkali or .001 mol of acid

caused cessation of development in the eggs of a European sea urchin. Slight increase in alkalinity causes an increase in growth and cell division, while very small additions of acid inhibited these processes. Whitley (28) found further that the same relations obtained in the case of the developing eggs of plaice. It is difficult to say how much the addition of alkali and acid modified the concentration of hydrogen and hydroxyl ions in the case of the experiments of these investigators or my own, because the determination on ion concentration requires special methods.

TABLE 6. *Showing comparative resistance of echinoderms, mollusks and barnacles from different depths, to fresh water.*

Scientific and Common Name	Depth at which commonly taken	No. experiments	No. individuals	Depth from which collected in meters	Time of exposure, in hr. or min.	Conditions at end of exposure
Balanus balanoides L. Shallow water barnacles	0	1	5	0	32 hr.	Alive
Balanus aquilla Spil. Deep water barnacle ...	20-40	1	5	20-40	32 hr.	5 dead
Mytilus edulis Lin. Shallow water mussel..	0-2	1	5	0-2	168 hr.	All alive
Modiolus modiolus Lam. Hairy mussels	0-125	1	5	125	168 hr.	3 dead
Leptasterias hexactis Stimp. Six-rayed star	0	1	3*	0	2940 min.	All dead
Henricia sanguinolentia Mull. Blood star	0-1000	1	3*	?	315 min.	Alive
		1	3	20-40	540 min.	Dead
Crossaster papposus Lin. Rose star	10-100	1	1*	20-40	100 min.	Alive
		1	1		315 min.	Dead
Pteraster tessalatus Ives. Cushion star	30-80	1	1*	80	45 min.	Alive
	30-80	1	1	80	100 min.	Dead
Gorgonocephalus eucnemis (M. & T.) Basket star...	40-175	1	1*	100	25 min.	Partially recovered died
		1	1	100	45 min.	Dead
Acmaea patina Esch. Limpet	0	1	2*	+2	113 min.	1 dead
Acmaea pelta Esch. Limpet	0	1	2*	+2	113 min.	1 dead
Acmaea mitra Esch. Limpet	0	1	2*	0	113 min.	Both dead
Calyptraea fastigiata Gld. Limpet	0	1	5*	0	85 min.	All dead

*Several additional experiments performed, part with similar results and part with a view to determine an exposure which would be likely to give differential results.

TABLE 7. *Showing the resistance of shrimps and crabs of the same and different species from different depths, to acidity.*

Scientific Name	Depth from which collected, in meters	No. experiments	No. individuals	% of N-10 Alk. to neutralize 1 liter methyl-orange indicator	Minutes to loss orientation	Total exposure in minutes	Condition at end of exposure
Pandalus danae Stimp............	4*	1	3	1	9	23	Alive
	60-100	1	3	1	10	2?	Dead
	4	1	2	33	8	18	Alive
	80	1	2	33	13	18	Alive
	100-150	1	2	33	?	18	Alive
	4*	1	3	100	10	55	Dead
	20	1	1	100	23	190	Dead
	100-150	1	1	100	81	180	Dead
	4*	1	5	127	6	13	Alive
	20	1	5	127	7	13	Alive
Pandalus stenolepis Rath.......	80-160	1	3	1	6	14	Dead
	50	1	2	100	13	87	Dead
	40-60	1	2	100	14	87	Alive
	170	1	1	100	18	100	Dead
Pandalus borealis Kroy.........	100	1	3	1	6	14	Dead
	100	1	1	33	8	18	Alive
Crangon alaskensis	4	1	1	33	12	62	Alive
	10-50	1	1	33	12	62	Alive
	80	1	1	33	12	62	Alive
Crangon communis Rath.........	100-150	1	1	33	12	62	Alive
Spirontocaris lamellicornis Dana	40-50	1	1	33	18	28	Alive
	110-150	1	1	33	8	28	Alive
Scyra acutifrons Dana..........	1	1	2	33	8	8	Dead
	40-50	1	3	33	63	63	Dead
	80	1	2	33	73	73	Dead
	100-150	1	1	33	28	28	Dead
Petrolisthes eriomerus Stimp...	0	1	3	100-120		117	Average to death
Cancer productus Rand..........	1-2	1	1	100-120		30	
	10-100	1	2	100-120		35	1 dead
Cancer oregonensis Dana.......						247	1 alive

When acid was added to the animals (*table* 7) they lost equilibrium in a short time. The length of time to lose equilibrium was clearly correlated with the depth from which they came, but the relation is reversed as compared with the results from fresh water and temperature. The animals which came from the greater depths lost equilibrium later than those from the shallower water.

Table 8 shows the relations to alkaline water. Here again the species from the greater depth showed the greater resistance to the alkali.

TABLE 8. *Showing the resistance of animals from differenth depths, to alkalinity.*

Scientific Name and Common	Depth from which collected, in meters	No. experiments	No. individuals	Cc.N-10 acid required to neutralize 1 liter phenolphthalein indicator	Depth at which commonly taken	Time of exposure, in minutes	Conditions at end of exposure
Pandalus danae	4***	1	5	41		19	5 on side
	20	1	5	41		19	3 on side
	4	1	2	*		60	Dead
	20	1	1	*		60	Alive
Pandalus stenolepis	100	1	1	*		60	Alive
Paracrangon echinata	10	1	1	41		67	Dead
	180	1	1	41		92	Alive
	180	1	1	41		92	Alive
	40-60	1	1	*		26	No response
Spirontocaris groenlandica Fabr.					560**		Recovered
	40-60	1	1	*	80-100	26	Responded
Spirontocaris lamellicornis	40-60	1	1	*		38	Moved
Crangon alaskensis		1	1	*			No response
Munida quadrispina Ben		1	1	*		25	No response
Hyas lyratus Dana Blunt-nosed crab	4-20	1	4	136	10-200**	24 hr.	1 alive
Scyra acutifrons Dana Sharp-nosed crab	4-20	1	9	136	0-80	24 hr.	4 alive
Pugettia gracilis Dana Graceful kelp crab	4-20	1	6	136	0-80	24 hr.	2 alive
Cancer productus Rand. Cancer crab	4-20	1	2	136		24 hr.	All alive
Cancer oregonensis Dana	4-20	1	2	136		24 hr.	All alive

*Decidedly alkaline to phenolphthalein; not titrated.
**Maximum depth recorded outside of Puget Sound.
***Green, from locality B, eelgrass.

IV. DISCUSSION AND CONCLUSION

These animals, specially those from the greater depths, were taken from deep water and placed in the float car under greatly reduced pressure and experimented upon a little later. Was the difference between those taken from the different depths in any way dependent upon the in pressure? To test this a set of animals was collected and kept in the float car covered with canvass for two weeks and the experiments repeated with results in accord with those secured at the beginning of that period. Since there was no essential difference in the character of the animals in these respects after such treatment, effects of pressure, temperature, etc., are in a measure eliminated. If pressure were responsible the removal to shallow water for two weeks would be likely to make some difference. Further the experiments of Regnard (22) tend to show that such small pressures are not of great effect. The few temperature determinations show that there is little difference between the different levels at which such species as the coon-stripe shrimp (*Pandalus danae*) occurs. Such differences as exist are between the shallower layer over the rocks at the shore and the layers immediately beneath. Temperature responses can hardly be responsible. When one considers the differences in conditions in the different habitats he is somewhat at loss to explain the diffrences noted.

Strong tides and complete circulation of the water would lead one to expect only small differences in the chemical character of the water, but the differences between the two sides of the harbor make such conclusions unwarranted. It was impracticable to determine the chemical character of the water from the deeper parts because of the absence of a suitable water bottle.

Of the differences in habitat relations which have been noted the difference in light is the most striking. Turning to table 5, we find that the crabs which live under stones and in the dark on the shore (flat shore crabs), die quicker than crabs of greater depths that live more of the time in the light.

The color differences in the various crustacea, which corresponds to the background in individuals from red and green algae, and which according to Gamble (8) is paler from greater depths, makes color the only character correlated with the different physiological states; and this has been demonstrated to be determined by light. Gamble's (8) experiments showed that animals take on the color of their background only in the young stages. Thus light may be a correlative of factors causing the differences. The recent experiments of Smith (26) on salmon further show the importance of light. The remarkable differences displayed are

sufficient to justify further investigation of the subject and to call into question the validity of conclusions as to the uniform character of animals living under obviously different conditions.

The Department of Zoology at the University of Illinois supplied the map and bore part of the expense of the preparation of the paper for the press. The expense of the investigation was borne by the Puget Sound Marine Station.

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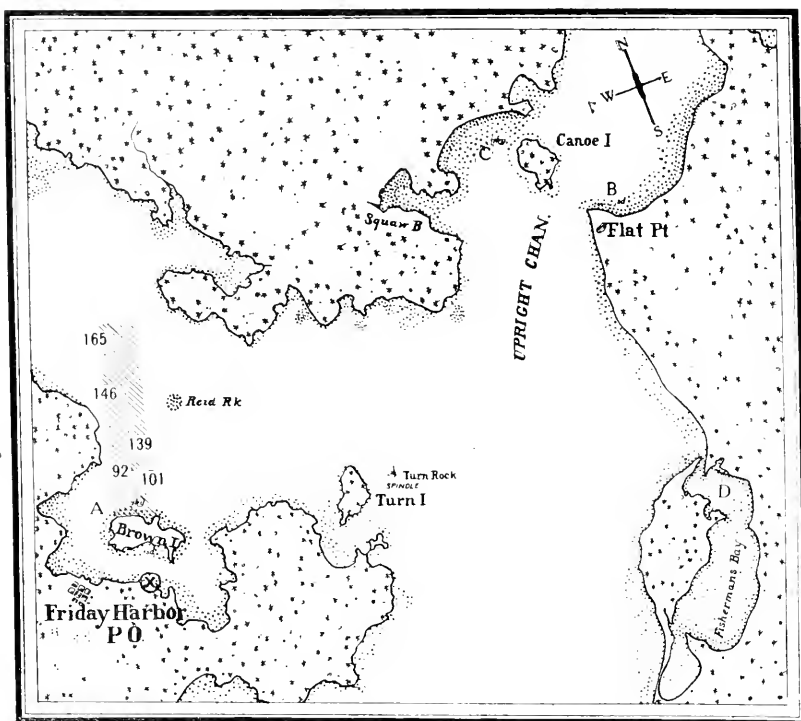
PLATE 29

Showing the vicinity of Friday Harbor. X indicates the location of the station building. The area shaded with oblique lines is the area from which most of the materials used were obtained and the area on which Miss Perry made an intensive study of distribution (Puget Sound Marine Sta. Pub. 1:175-176. 1916). The figures given are depths in meters. A, B, C, and D, are localities from which some other material used in experiments was obtained. These are referred to in footnotes in connection with the tables.

DISTRIBUTION OF CERTAIN INVERTEBRATES ON A RESTRICTED AREA OF SEA BOTTOM*

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The following table shows the distribution of the common Arthropods, Echinoderms, and Mollusks on the area northeast of Brown Island, shown by oblique rulings on the map on page 174 of the preceding paper.** The distribution as given is for the month of July, 1915, and for the area in question only. The species are arranged according to their uppermost limit. Relative abundance and habitat are indicated by figures and letters: —1, abundant; 2, common; 3, few; 4, incidental or accidental; r, on rocks; u, under rocks; s, sand; l, algae; m, rock beds.

		Shore			Lami-narian			Coralline			Subcoralline			Habitat
		Depth in Meters												
Scientific Name	Common Name	3	2	1	0	10	20	40	55	100	139	146	165	
Littorina scutulata Gld.	Snail	2	2											r
Littorina sitchana Phil.	Snail	2	2											r
Acmaea persona Esch.	Limpet	2	1											r
Acmaea pelta Esch.	Limpet	2	2											r
Hemigrapsus nudus Dana	Purple shore-crab	3	2		2									u
Thais saxicola Val.	Snail		2		3									r
Paphia staminea Conr.	Clam		2											s
Thais canaliculata Ducl.	Snail		2	1										r
Balanus balanoides L.	Barnacle		2	2										r
Mytilus edulis L.	Mussel		2	2										r
Acmaea patina Esch.	Limpet		2	2	3									r
Bittium eschrichti Midd.	Snail		3	2	2									ru
Macoma nasuta Conr.	Clam			1	2									s
Leptasterias hexactis St.	Six-rayed star			1	2									lu
Pisaster ochraceus Br.	Common starfish			2	2									r
Petrolisthes eriomerus St.	Flat shore-crab			2	2									u
Lophopanopeus bellus St.	Black-claw crab			2	2									u
Cucumaria miniata Br.	Cucumber			2	2									u
Cardium corbis Mar.	Clam			2	1	1	2	3						s
Marcia Kennereyi Rve.	Bivalve			2	2	3	3	3	3	3				s
Acmaea mitra Esch.	Limpet			3	2									r
Chrysodomus dirus Rve.	Snail			3	2	3								r
Margarites lirulata Cpr.	Snail			3	2	2								l
Margarites pupilla Gld.	Snail			3	2	2								l
Fissuridea aspera Esch.	Limpet			3	2	2								r
Calliostoma costatum Mart.	Snail			3	3	2	2	2	2	1				lr
Trepidula nivea Adams	Slipper shell			3	3	2	2	2	1	2	2			r
Strongylocentrotus drobachiensis Mull.	Urchin			4	1	1	2	2	2	2	2	2	2	r

Scientific Name	Common Name	Shore			Lami-narian			Coralline		Subcoralline			
		3	2	1	0	10	20	40	55	100	139	146	165
Lacuna porrecta Cpr.	Snail				1	3							
Hapalogaster mertensii Br.	Crab				2								
Telmessus cheiragonus Til.	Helmet crab				2								
Pugettia gracilis Dana	Graceful Kelp-crab				2								
Epialtus productus Rand	Crab				2	2							
Cancer magister Dana	Crab				2	2							
Cancer productus Rand	Crab				2	2							
Cucumaria california Semper	Large cucumber				2	1	2	3	3				
Calyptraea mamillaris Brod.	Chinese Hat				2	2	1	1	2	3			
Psolus chitonoides Clk.	Cucumber				2	2	2	2	2	2	2	2	
Pecten giganteus Gray	Scallop				3								
Strongylocentrotus franciscanus Ag.	Urchin				3	1							
Oregonia gracilis Dana	Crab				3	2	2	1	2				
Crangon alaskensis Lock	Shrimp				3	2	2	2	3	3			
Cardium californiense Desh.	Bivalve				3	3	2	1	2	3	3		
Ceramaster granularis Retz.	Star fish				3	3							
Chrysodomus tabulatus Baird	Snail				3	3	3						
Pisaster paucispinus St.	Star fish				3				3				
Cancer oregonensis Dana	Crab				3	3	3	1	2	2	3		
Henricia sanguinolenta Mull.	Blood star				3	3	3	2	3	3	3	3	
Laqueus jeffreysi Dall.	Brachiopod				3	3	3	3	1				
Calliostoma annulatum Mart.	Snail				3	3	3	3	2	2	2	3	
Hyas lyratus Dana	Crab				3	3	3	3	2	2	2		
Monia macroschisma Desh.	Rock Oyster				3	3	3	3	2	3	3		
Pycnopodia helianthoides Brant	20-rayed star				3	3	3	3	3				
Trichotropis cancellata Hds.	Snail				3	3	3	3	3				
Purpura foliata Mart.	Snail				3	3	3	3	3	3	3	3	
Pecten hindsii Cpr.	Scallop				4	3	2	1	1	2	2	3	
Pecten hericeus Gld.	Scallop				4	3	2	1	1	2	2	3	
Pandalus danae St.	Coon-stripe shrimp				4	3	2	2	3	3	4		
Crangon communis Rath.	Shrimp				4						2	2	
Thais lamellosa Gmel.	Snail					2							
Balanus aquilla Spill.	Large barnacle					2	2	2	2	2	?	?	
Mytilimeria nuttallii Conr.	Clam					3							
Solen sicarius Gld.	Clam					3							
Cucumaria chronhjelmi Theel.	Cucumber					3	1	2	2	3			
Scyra acutifrons Dana	Crab					3	3	2	2	3			
Spirontocaris lamellicornis Dana	Shrimp					3	3	3					
Crangon munita Dana	Shrimp					3	3	3					
Paracrangon echinata Dana	Shrimp					3	3	3	3	3	3	3	
Argobuccinum oregonensis Redf.	Snail					3	3	3	3	3	3	3	
Terebratalia obsoleta Sow.	Brachiopod						2	2	2	1	1	1	
Leda minuta Fabr.	Bivalve						3						
Modiolus modiolus L.	Mussel						3	2	1	2	3	3	
Munida quadrispina Ben.	Shrimp-crab						3	3	3				
Puncturella cucullata Gld.	Limpet						3	3	3				
Crepidula dorsata Brd.	Slipper shell						3	3	3				
Crepidula adunca Sry.	Supper shell						3	3	3				
Terebratulina unguicula Carp.	Brachiopod						3	3		2	2	3	
Astarte alaskensis Dall.	Bivalve						3	3	3	3	3	3	
Gorgonocephalus eucnemis (M. & T.)	Basket star						3	3	3	3	3		
Crossaster papposus L.	Rose star						3	3	3	4			
Yoldia ensifera Dall.	Bivalve							3	3				
Lunatia pallida B. & S.	Snail							3					
Pandalus borealis Kr.	Pink shrimp							3	1	3			
Hemithyris psiltacea Gmel.	Brachiopod							3	2	2	2	1	
Venericardia ventricosa Gld.	Bivalve							3	3	3			
Calliostoma variegatum Carp.	Snail							3	3	3			
Pteraster tesselatus Ives	Cushion star							3	3	3			
Lepeta concentrica Midd.	Limpet							3	3	3	3		
Pandalus stenolepis Rath.	Deep coon stripe							3	3	3	3	2	
Rhinolithodes wosnessenskii Br.	Crab							4					
Dermasterias imbricata Grube	Starfish												
Henricia leviuscula St.	Orange star								3				
Lopholithodes foraminatus Stimp.	King crab									3	3		
Spirontocaris polaris Sab.	Shrimp									4			4
Ocinebra lurida Midd.	Snail										3	3	3

Variation Induced in Brachiopods by Environmental Conditions[1]

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In classifying fossil brachiopods the paleontologist frequently finds forms that are intermediate between two allied species, and even at times between closely related genera. Often transitional forms grading from the parent stock to the new species are found, thus conclusively showing their evolution. He is sometimes at a loss for a classification for these forms, and, perhaps in some cases, several species have been made of the variations of one species.

For some time the writer has been interested in these variations and has been seeking to find what causes would bring about such changes, and where the division lines between species should be drawn. The fact that similar variations are found, to a greater or less degree, in many different species, led to speculation as to whether they were caused by similar conditions of environment, and whether environment was the sole cause of these variations, or whether there was an innate tendency in the individuals to develop along certain lines.

Several papers on variation in brachiopods have been published, variations have been measured and curves plotted to show the tendencies and amount of the variation. In one case[2] variation was ascribed to innate tendencies in the individual, but in the other papers[3] no causes were suggested.

It was evident that the first step in solving the problem of the cause of variation in brachiopods should be to make a study of the living forms, their habits of life, and their response to the physical conditions of their environment. For this purpose a trip to the San Juan region of Puget Sound was made during the summer of 1915, and collections of the brachio-

[2] Wilson, Miss A. E., Museum Bulletin No. 2, Canadian Geol. Survey.

[3] Cumings, E. R., and A. V. Mauck, Amer. Jour. of Sci., XIV, July, 1902. Grabau, A. W., and Margaret Reed, 7th Intern. Zool. Cong., Proc., 1910. Mook, C. C., Annals of the N. Y. Acad. Sci., Vol. XXVI, 1915.

pod fauna were obtained, with complete data on the habitats from which they were secured.

The San Juan region of Puget Sound consists of a group of islands separated by glaciated channels from 20 to 90 fathoms deep. These channels are the chief points of entrance and escape for the tide waters of the Gulf of Georgia, a body of water lying directly to the north. The water rushes thru the narrow channels at a velocity of 7 to 10 or more miles per hour, thus sweeping the rocky points and the bottom clean of debris and furnishing an excellent habitat for brachiopods. These animals are sessile in the mature stage and are generally confined to rocky shores and bottoms. In this study a situation thruout which the same physical conditions of environment persist is called a habitat.

Four species of brachiopods were found at various depths (*table* 1) in the region studied.[4]   On account of its wide distribution, i. e., its presence in many habitats, *Terebratalia obsoleta* Sowerby was selected for this study. Collections were made from the strand line to 90 fathoms. The specimens from along the strand line and to a depth of about two fathoms were made from a canoe, those from below the water being taken by means of a scraper with a net attached. The collections from deep water were taken by means of a dredge, which was worked from the deck of a steam trawler.

TABLE 1.   *Showing depth at which species were found and depth of maximum abundance*

Species	Range in depth	Maximum abundance
Laqueus jeffreysi Dall............	0 to 50 fathoms	30 fathoms
Terebratulina unguicula Carpenter.	30 to 60 fathoms	50 fathoms
Hemithyris psiltacea Gmelin	30 to 90 fathoms	90 fathoms
Terebratalia obsoleta Sowerby	0 to 90 fathoms	80 fathoms

When the collections were made complete data were taken as to depth, character of the bottom, exposure to wave action, tidal currents, and other physical conditions which might have some bearing on the problem. All of the specimens taken were saved. The localities at which the collections were made are numbered consecutively on the map (*plate* 30).

The specimens from locality No. 1, on the east shore of Turn Island, were obtained from about the mean tide line down to two fathoms below the low tide line. These specimens lived where they were subjected to strong wave action and to strong tidal currents. The currents here and at Cattle Point are the strongest in the vicinity of San Juan Island.

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[4]These species were kindly identified by Dr. Wm. H. Dall, of the National Museum, Washington, D. C.

The specimens from Cattle Point, locality No. 2, were brought up from 40 fathoms in the narrow channel between the southern extremities of San Juan and Lopez islands. The tidal currents keep the bottom swept clean, and the animal life is very scanty with the exception of hydroids and bryozoa, which are abundant.
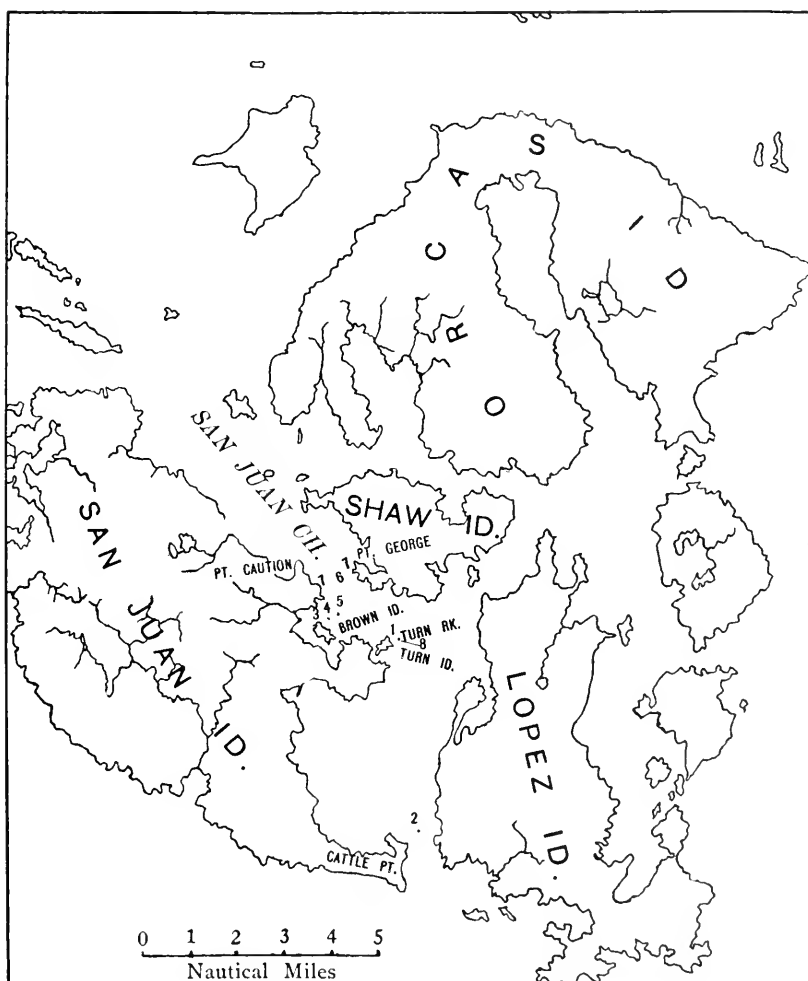
PLATE 30

The San Juan region of Puget Sound. Numbers 1-8 indicate the localities where the brachiopod collections were made.

The specimens from the north side of Brown Island, locality No. 3, were rock-sheltered forms. They were further protected by a growth of *Fucus* or seaweed. The individuals here were subjected to the force of the waves to some extent, but not as much as were those at Turn Island.

The specimens from 35 and 50 fathoms, localities No. 4 and No. 5, from the channel northeast of Brown Island, were subjected to wave and current action varying in degree with their depth.

The specimens from locality No. 6, from 80 to 90 fathoms in the San Juan Channel, are from comparatively quiet water, the normal condition for the best brachiopod habitat.

The specimens from locality No. 7, from 10 to 80 fathoms, were taken by a continuous drag across San Juan Channel from a point half a mile south of Point Caution, on San Juan Island, thru 90 fathoms in the middle of the channel up to 20 fathoms near Point George on Shaw Island. It is thus a mixture of the specimens exposed to the action of the waves and currents and of those from the comparatively quiet waters of the deeper portions of the channel.

Turn Rock, locality No. 8, is a rock projecting above the low tide line at about one-sixteenth of a mile east of Turn Island. It is completely covered at the highest tides. Three specimens were obtained from this place, two from sheltered crevices, the other exposed to the waves and currents.

The embryonic brachiopods pass thru a free-swimming stage which lasts for several days. During this time they are carried about by the waves and currents and are thus introduced into all habitats. The young of the shallow water forms and the young of the deeper water forms are thoroughly mixed. At the proper stage of development the animal attaches itself to some foreign object, becomes sessile, and begins to develop the shell or protegulum.

The specimens in the young shell stage, including all from 2.5 to 5 mm. in width, were carefully measured to find if there was any variation in the shell form which might have been inherited. No variation could be detected in the specimens from the same habitat or in those from different habitats.

In the older stages, including all specimens over 5 mm. in width, the shells varied with the conditions under which they grew, from wide spirifer-like to round, almost smooth forms, the extremes being in the mature individuals (*Figs.* 1-4, *plate* 32).

The marked tendencies of the variation seemed to be a shortening of the shell and a rounding of the anterior angle. These characters were

considered in measuring the variation. The length of the shell divided
by the width was taken as the index of the shell. The measurements were
made with a vernier caliper[5] (*plate* 31) and are accurate to .05 mm. The
angle considered is the angle made by the valves at the anterior margin.
The measurements were made with a contact goniometer and are accurate
to .5 degree. The average of all the indices of the individuals of a habitat
was taken as the index of the habitat.[6] A glance at the figures in table

TABLE 2. *Showing indices and anterior angles of shells from various*
depths.

Habitat	No. Shells	Index	Aver. Angle
No. 1. Turn Island 80		.824	84
No. 2. Cattle Point 5		.853	81
No. 3. Brown Island 16		.868	78
No. 4. 35 fathoms 45		.883	77
No. 5. 50 fathoms 95		.887	77
No. 6. 80-90 fathoms 53		.895	70
No. 7. 10-90-20 fathoms 837		.884	77
No. 8. Turn Rock ⎧ unprotected 1		.840	85
⎨ .. 1		.865	78
⎩ protected......... .. 1		.870	77

2 will show that there is a definite tendency toward the development of
the shorter, more gibbous shells in the habitats where the animals are
exposed to rough water. The same result is produced by the strong wave
action at the surface and by the action of strong currents below the sur-
face. This result is to be expected when the manner of growth of the
brachiopod is considered. Professor H. W. Shimer. in his work entitled
"An Introduction to the Study of Fossils," says concerning their growth:

    "The soft body of the animal, lying at the posterior portion of the
shell, occupies only about one-third of the interior. The body wall gives
off two folds or mantles, one fitting closely to and secreting the pedicle
valve, the other secreting the brachial valve.............. Any marked
injury to a mantle is necessarily reflected in the shell. If something in-
jures a mantle edge, the first process in healing is a puckering up of
the mantle around the injured place..............which causes a like
puckered appearance in the shell at that place; as the mantle becomes
nealed the growth lines of the shell become more and more regularly

spaced." (*Figs.* 5-8, *plate* 32). "But since an injury to one mantle causes a lessened vitality, even if very slight, of the entire animal, the opposite mantle (*shell*) likewise displays a crowding and general interruption of regularity in the growth lines. It thus follows that the life history of
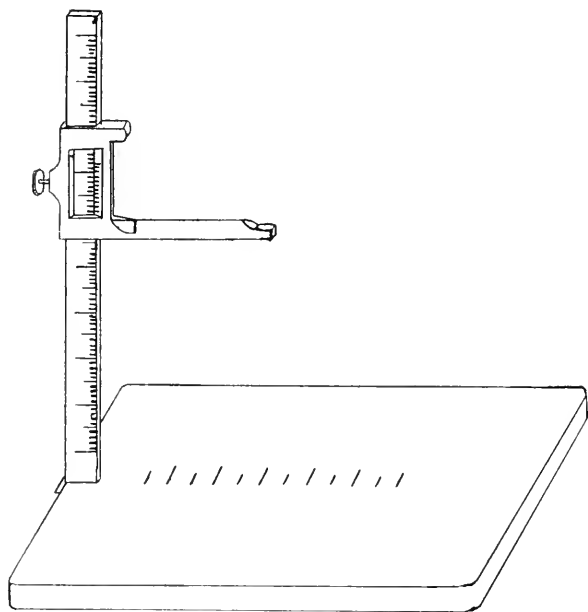
PLATE 31

Vernier caliper for measuring specimens.

the individual can be read from the beak forward, not only in relation to the shape and size of the shell, but to its injuries, social crowdings and general health."

Consistent with this statement, the suggestion is offered that the irritation or slight but constant injury, caused by the waves and currents slightly bruising the tender edge of the mantle, would produce the same effect all along the anterior edge of the shell. Continued indefinitely, this action would result in the development of the gibbous form of the shell, finally presenting a rounded front to the rough water. Altho temperature, salinity, light, and various other factors may be important in the growth and general health of the brachiopods, the evidence brought out by this study seems to warrant the conclusion that the variations in the brachiopod shells described above are due chiefly to the irritating action of rough water, and are not to be attributed to any inherent tendency.

By working out the relationships between the variation of individuals and the physical conditions of the habitat in this manner, the paleoniologist may be able to throw much light on the conditions under which some of the fossil forms lived. The writer has in progress such a study of the variation of the Devonian brachiopod, *Stropheodonta demissa* (Conrad), as shown in the Devonian (Hamilton) of the northwest province, which promises very definite results.
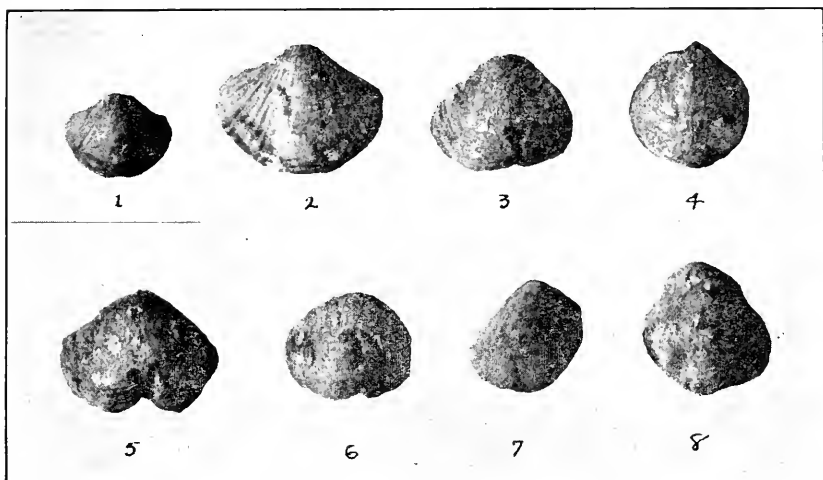
PLATE 32

View of shells of *Terebratalia obsoleta* Sowerby, showing variation resulting from difference in habitat, injury, etc.

Figs. 1, 2.   Normal shaped specimens from quiet water.

Fig. 3.   Specimen showing some effect of rough water.

Fig. 4.   Typical tide-line specimen from Turn Island.

Fig. 5.   Effect of local injury. The growth lines have "a puckered appearance."

Fig. 6.   Specimen with such an injury healed. The growth lines have gradually resumed their regularity.

Figs. 7, 8.   Effect of injury to one side of the mantle.

Factors Influencing the Growth and Distribution of Nereocystis Luetkeana

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It is obvious to even the casual observer that the length of the stipe of *Nereocystis luetkeana* is largely determined by the depth of the water in which it grows. Kelps growing in deep water may reach a length of 18 meters, while plants nearer shore are shorter, those attached near the low tide line rarely exceeding three or four meters. Rigg (24) notes that *Nereocystis* reaches its best development in water 8-10 fathoms deep. Experiments were carried on at the Puget Sound Marine Station in the summer of 1916 to determine whether darkness or the mechanical stretching of the stipe by the upward pull of the bulb causes the more rapid growth of a deeply submerged kelp. Either explanation would account for the facts; because when the kelp reaches the surface of the water the pull of the bulb on the stipe is lessened, hence the rate of growth if affected by tension might decrease; or if the chief factor were light intensity, the bright light at the surface might retard elongation.

It is commonly known and has been experimentally proved in many cases that darkness stimulates and bright light retards growth. The experimental work cited by Pfeffer (23) and Jost (15) is evidence of the retarding action of light on the growth of leaves, stems and roots of the flowering plants. According to Jost, there is a maximum light intensity "affecting the generality of plants which, when exceeded, first retards growth, and finally causes death. The position of the maximum is very varied. It lies very low in shade-loving plants such as we find abundantly in woods, or more especially in the sea."

Similar results have come from work on thallophytes. According to Vines (29) Brefeld found that the hypha bearing the sporangium of *Pilobolus microsporus* grows to be eight or ten inches long if grown in darkness, while usually it does not exceed one-half inch; and that the stipe of *Coprinus stercorarius*, usually about an inch long, may become two feet long in the dark. Klein (16) (Rev. Bot. Centralb.) concludes that light is the chief factor in the production of conidia in *Botrytis cinerea* from the fact that the spores are produced so much more abundantly at night or when darkened in the daytime. He reports similar results from

Rindfleisch and De Bary. Vines (29) says that light exercises a retarding influence on the growth of the sporangiferous hyphae of *Phycomyces.* Jost refers to Stameroff's data showing increased rate of growth of the conidiophores of *Mucor* when darkened. Gränz (13) records similar results. Lakon (17) describes the favoring influence of darkness on the vegetative growth of *Coprinus.*

The destructive effect of sunlight on bacteria has been demonstrated many times. Ewart (7) says that both chromogenetic and non-chromogenetic bacteria including those which contain chlorophyll and grow normally when exposed to diffused daylight may be killed by the prolonged exposure to direct sunlight, and that even the vitality of the spores may be affected.

The work on algae has been rather limited. Berthold (7) (Rev. Bot. Centralb.) found that intense light causes increased rate of elongation at first, followed by retardation, then entire cessation of growth if the illumination is continued. According to Pfeffer, Kny reports more active growth of *Coleochaete* on the illuminated side; Noll and others found that the "chlorophyllous assimilating branches of *Caulerpa* and many other algae develop mainly on the side exposed to light." In Oltmann's (19) experiments, however, the effect of light was to inhibit germination and vegetative growth, and to accelerate spore formation. Ewart (6) states that the green zygotes of *Hydrodictyon* may remain living if dried in darkness, but if exposed to light, become decolorized and die. That there is difference of opinion as to whether sunlight is beneficial or injurious to algae is shown by the following sentence taken from West and West (30): "In the paper by Mr. Ewart we find the following statement: 'It is well known that prolonged exposure to direct sunlight is fatal to   .   .   .   many algae.' From our own experience we should at once say that nothing could be more beneficial to Freshwater Algae than prolonged exposure to direct sunlight, provided they remain under natural conditions." An example is given of accelerated growth in lower green and blue-green algae exposed to direct sunlight all day. In Ewart's next paper (7) he explains that direct sunlight on a pond may not penetrate the water because of reflection and refraction at the surface. He experimented on the resistance of *Chara* to strong light and found that the end cells are bleached after 6-8 hours' exposure to continuous sunlight, death following bleaching when the whole cell is exposed. According to him *Spirogyra* is bleached by one day's exposure to direct sunlight and temporarily loses its power of assimilation. Schimper (25) says that intense light is fatal to protoplasm independent of the action of heat; and that algae are specially sensitive, some being killed by the increased

light intensity as the season advances.   Combes (4) (Rev. Bot. Centralb.) reports that the optimum light intensity for *Cystococcus* and *Chlorella* is much less than direct sunlight, and that *Chlorella* can live only in weak light.

The exact mechanism of the changes produced in plants by change in light intensity is unknown.   It has been shown specially by the work on fungi that they are not to be accounted for through photosynthetic changes.

Mechanical stretching has also been said to cause superelongation. Jost says that increase in growth as the result of tension is easily proved by stretching a stem with a weight.   However he reports Elfving and Schwarz as finding that rate of growth is not affected by increasing or decreasing the centrifugal force acting upon stems attached to a rotating disc.   Hus (13) accounts for an unusually long specimen of *Porphyra perforata* f. *lanceolata* as being the result of continued pulling in one direction by waves.

The writer's experiments on *Nereocystis luetkeana* prove conclusively that those plants attached to the bottom grow more rapidly than those floating on the surface of the water attached to a raft, although growth is not affected by the detachment from the natural foothold (8, 28).   This was shown by artificially attaching one of two similar series of kelps to rocks and lowering the rocks until the bulbs were about 4.5 m. below the surface of the water.   The corresponding series were fastened by their holdfast ends to a raft and allowed to float on the surface.   At various intervals the lengths of the stipes were measured and recorded.   A comparison of the rates of elongation of the kelps growing in the two positions (*table* 1) shows that the more rapid growth takes place in the submerged, erect kelp.   This same fact might be deduced from observation. All those plants found growing attached to floating logs or docks, lying continually on the surface of the water, were very short, rarely exceeding a meter in length even when mature; while specimens submerged just below them had the normal elongation for their depth of at least three meters.

TABLE 1.   *Comparison of the elongation of the stipes of submerged and floating plants.*

Submerged plant 1.85 m. in length elongated 14 cm. in 18 days.
Floating plant 1.88 m. in length elongated 1.25 cm. in 18 days.

Submerged plant 1.65 m. in length elongated 40.5 cm. in 18 days.
Floating plant 1.35 m. in length elongated 12.0 cm. in 18 days.

Submerged plant 2.65 m. in length elongated 91 cm. in 30 days.
Floating plant 2.71 m. in length elongated 30 cm. in 30 days.

Two conditions of growth which were different in the two environ-
ments were tension in the stipe of the plant produced by the buoyant force
of the pneumatocyst, and light intensity. To determine if either is a
controlling factor in elongation it was necessary to experiment first on
the effect on the rate of growth of various tensions in the stipe, the light
intensities remaining equal; and second, on the effect of different light in-
tensities, the stretching of the stipes being equal.

The different tensions in the stipe were secured by weighting the
holdfast end with rocks of various sizes. The head of the kelp was at-
tached to the raft by means of a padded wire ring just below the bulb.
A cord was slipped through this ring and tied to a staple on the raft, thus
allowing the kelp to hang in the water with the whole weight of the rock
at the lower end pulling on the stipe. The loose wire rings were used
instead of muslin strips which were tried at first, because of the rapid
decay under the cloth when in intimate contact with the stipe. The ring
touched the stipe in only one place, and although eventually it began to
cut in, decay was much less rapid. The bulbs and fronds were all about
5 cm. below the surface of the water. The weights pulling downward on
the stipe produced tensions equal to those which would be produced by
the upward pull of bulbs whose buoyant force equaled the pull of grav-
ity on the rocks.

The kelps in each series of experiments were chosen as nearly alike
as possible as to age, length, extent of growing region, condition, and
number of fronds. One kelp in each series was weighted with a small
rock of about 200 grams which was carefully chosen to balance the up-
ward pull of the bulb as nearly as possible. Other plants were stretched
by weights of 700 grams and still others by as much as 2,000 grams. It
was expected that those stretched by the heavier weights would elongate
most rapidly, and that those which were not stretched would grow more
slowly. However, data from a sufficient number of experiments was se-
cured to show that there is no relation between rate of growth and me-
chanical stretching in the stipe, for those plants in which the pull of the
bulb was just balanced by a small weight elongated as rapidly as those
stretched by the heavy rocks, and in some cases even more rapidly.

A second set of experiments had for its object the determination of
the effects of darkness and of bright light on the rate of elongation of
similar kelps, the tensions in the stipes being equal. Equal tensions were
secured by picking out plants for each series whose bulbs by virtue of
their equal size were of equal buoyant force. By sinking one kelp of
each series about 4.5 meters and the other 5 cm. below the surface, the
stimulating effect of darkness was demonstrated. Both kelps grew in

their natural position. The holdfasts were bound to rocks by muslin strips and cord, and the rocks lowered by strings from the raft. Table 2 is a comparison of the rates of growth induced by the two environments, and indicates that darkness is a large factor in the elongation of the stipe of *Nereocystis*.

TABLE 2. *Comparison of the elongation in 10 days of plants deeply submerged with those near the surface.*

Plant 1.9 m. in length with bulb submerged 4.6 m. elongates 7.5 cm.
Plant 1.7 m. in length with bulb submerged 5 cm. elongates 3 cm.

Plant 3.42 m. in length with bulb submerged 4.6 m. elongates 13 cm.
Plant 3.84 m. in length with bulb submerged 5 cm. elongates 5 cm.

Plant 3.93 m. in length with bulb submerged 4.6 m. elongates 19 cm.
Plant 3.73 m. in length with bulb submerged 5 cm. elongates 13 cm.

The failure of all attempts to secure growth in darkness by means of hoods of black cloth should be noted here. Strips of black lining 24 cm. wide and as long as the stipe to be covered, were sewed up one side so as to enclose the plant in a tube the ends of which were drawn up by gathering strings and tied. In every case the stipes and fronds covered soon ceased growing, and decayed rapidly, some plants being quite soft at the end of eight days. In one case in which the stipe grew only 1 cm. in 16 days and was still alive at the end of that time, the covering was removed with the result that at the end of the next 6 days it had grown 2.5 cm. Occasionally no elongation takes place after the hood is put on, and the plant soon becomes soft. The cause of death is probably interference with the gas exchange. It would be interesting to try darkening by means of hoods held open at both ends by wire rings, since this arrangement would allow free access of water to the plant.

Observations on the size of *Nereocystis* plants growing in different environments in the vicinity of the Marine Station confirm the supposition that it cannot be differences in mechanical stretching which cause the variations in the length of the stipe, and that it may be differences in light intensity. From the unusual length of the stipes growing in the swift current in San Juan Channel—some of them 18 meters long—it might appear that the stretching to which they are subjected is a cause of their rapid growth. But not far distant are other kelps growing in water flowing just as swiftly which rarely exceed 60 cm. in length. They are in the shallow tide stream which fills and empties the Argyle lagoon. The bottom is gravel for the most part with an occasional rock large enough to anchor a kelp. These plants are often curiously misshapen. Many have fronds 60 cm. long and bulbs of normal size but very short stipes. One was found with a bulb 6 cm. in diameter and a total length from holdfast

to base of fronds of only 23 cm. The largest one measured was 55 cm. These kelps are mature; and that they have ceased growing is evident from the dark color and tough texture of the stipe (9). They are kept stretched out nearly horizontal by the rush of water upstream or down- stream, but they do not elongate as a result of it, although the super- elongation of a specimen of *Porphyra perforata* f. *lanceolata* was accounted for by Hus (14) as due to the stretching to which the plant was subjected every time a wave rolled in or out. However the explanation for the under-development of the Argyle kelps may be found in the bright light in which they grow since the shallowness of the water means almost un- diminished illumination. The fact that the plants growing in currents are longer than those in quiet water of the same depth may be very easily accounted for as conditioned by light intensity when one sees how much more deeply the bulb of any kelp is submerged when a strong tide is run- ning than it is at slack tide. The current tends to hold the kelp in the direction in which it is flowing. The stipe will take the position in the water which might be represented as the resultant of two forces, the one the current pulling horizontally from the attachment, the other the buoy- ant force of the bulb pulling upward. By taking this diagonal direction the kelp is in darkness or dim light for a much longer time than is the erect kelp in quiet water.

That more light enters water when its surface is smooth was shown experimentally* by agitating the surface of a tub full of water which had a piece of glass 45x12 cm. in the bottom, and roughly measuring the light coming through by its effect on ordinary photographic printing paper. The source of light was a 40 watt mazda incandescent globe held by a clamp to a piece of iron pipe fastened at one side of the tub and bent over it so as to form an arc, every part of which was 30 cm. from the sur- face at the center of the tub. The tub was 60 cm. in diameter and the water was 22 cm. deep. The whole apparatus was 25 cm. from the table so that the sensitized paper could be exposed directly under the glass. To guard against reflected light affecting the paper, all near-by surfaces were painted black including the tub, and the room was completely dark- ened. The luxometer would not give results because the flickering on the illuminated surface made an accurate judgment of the intensity impos- sible; so the total amounts of light transmitted through the water in equal intervals of time as evidenced by the darkening of sensitized paper were compared. Exposures were made with the light 45° from the edge of the tub, which corresponded to the sun's position in mid-afternoon, and

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*This experiment was suggested by Dr. F. A. Osborn, head of the physics department of the University of Washington.

with it at 90°. One half of a piece of Contrast Cyko paper was exposed 30 sec. with the water quiet, and then the other exposed for exactly the same length of time with the surface very much agitated by rotary stirring at the edge of the water. The paper was then developed in the ordinary way and in every case that half of the sheet which had been exposed under still water printed darker, showing that a rough surface keeps out some of the light which would otherwise be transmitted. Also, there was greater contrast between the two when the exposures were made with the light 45° from the horizon, indicating that when the sun is below the zenith rough water reflects more light in proportion than at noon. However, it is by no means certain that the difference in the amount of light penetrating smooth and rough water is enough to be a real factor in the explanation of the elongation of kelps in currents.

The better aeration of the water and larger amount of carbon dioxide available where water is constantly in motion has been suggested as a reason for the distribution of *Nereocystis* in swift tides and currents, and its absence in quiet waters, noted by MacMillan (18), Frye (10), Setchell (27), Rigg (24), and Peters (22). This factor cannot be the sole one operating, or the kelps in the Argyle tide stream would be very long instead of very short; for the water there is thoroughly aerated as it rushes like a river over stones and other obstructions in its bed. MacMillan suggests that the preference kelps have for moving water may be due to the fact that when a tide is running the leaves are always submerged, and so are protected from the friction resulting from impact with the surface. It might be added that they are also more protected from exposure to heat and drying. Frye attributes their absence in quiet water to the difficulty of gas exchange which may be due in part to the suspended material deposited on the plant there. Peters notes the fact that in quiet water the plants are often covered with a slimy coat of diatoms and other epiphytes such as *Ulva fasciata*. Rigg refers to the demand for gases as bearing on the question and points out the greater supply of oxygen and carbon dioxide available in moving water. Setchell says that *Nereocystis* will not grow in quiet waters and "if their accustomed haunts are shut off from full influence of the swells, they perish and are not renewed." He cites a case at San Pedro, California, where a breakwater was constructed. Since Peters has shown the destructive effect of the snails which infest the plants of quiet water and cannot grow on those of swift currents, it seems probable that the presence of epiphytes and parasites may be a large factor in the problem. The unusually fine specimens found in the San Juan channel which are free from those parasites which are so conspicuous on the smaller plants near shore, lends color to this explanation.

Chambers (3) says that currents are beneficial by renewing the CO_2 supply and by removing the depleted water and gas from the surface of aquatic plants. He shows that bicarbonates are a source of CO_2, as Hassak, Angelstein and others have already pointed out, and that a CO_2 saturated medium does not stimulate growth, which would indicate that the value of currents to plants is not in aeration but in carrying away the water depleted of CO_2. Undoubtedly a gas film surrounds the plant and interferes with absorption. But Chambers points out that Schützenberger found that the optimum CO_2 supply for water plants is only 5% to 10% of complete saturation. Since the tides keep the water around the kelps of the most quiet bays constantly moving it is hard to conceive of a shortage of CO_2 except by assuming a depleted layer of water and gas held so tightly to the surface of the plant by cohesion that ordinary tides are not capable of removing it as fast as the gas is taken from it. The facts which must be known before it can be proved conclusively what part currents play in the growth of kelps or any other plant are: the velocity of immediately adjacent water compared with the velocity of the current; the width of the layer held so long that it becomes seriously depleted of gas or saturated with waste products; the total amount of CO_2 available in carbonic acid, bicarbonates, and as free gas; the rate of their diffusion from the rapidly moving water through the depleted layer to the plant; and the optimum rate of absorption of gas by the plant.

Temperature may also be a factor in the distribution of *Nereocystis* (27). The water of the quiet bays is undoubtedly warmer than that of channels where the tides are swift; and it is conceivable that high temperature may have something to do with the stunted development of the kelps in the Argyle tide stream, for the lagoon becomes quite warm at times. However an increased temperature of surface water is hardly sufficient to account for the differences in elongation of deeply submerged kelps and those which are near the surface. The slow rate of growth of floating plants may be partly due to their higher temperature and desiccation. Frye (12) presumes that the difference between the gas pressure in floating and submerged pneumatocysts may be attributed to difference in temperature.

Gravity might also be a factor in the slow elongation of the floating, horizontal kelps, and the more rapid growth of the naturally attached, erect ones. According to Jost, Elfving and Richter found that the growth of *Chara* and *Phycomyces* is retarded when the plants are inverted.

Salinity of the water may not be so large a factor in the distribution of *Nereocystis* as is generally supposed. Setchell (27) says that the *Laminariaceae* are most abundant where the salt water is not polluted by

the discharge of fresh water from rivers, but a few ascend tidal rivers to a slight extend.   Rigg (25) found that so far as the kelps near the mouth of the river Elwha are concerned, they do not grow in water which has not the normal salinity, but he recognizes other factors which may explain their absence at the mouth of the river.   Osterhaut (20) questions salinity as an explanation of the distribution of algae near the mouths of rivers, since he has found that they are not very sensitive to fresh water. He notes the red, brown, green, and blue-green algae growing on vessels plying between San Francisco and inland river points, and thus daily subjected to the extremes of fresh and salt water.   In another paper (21) he reports that algae grew a month in his laboratory in distilled water into which they had been transferred directly from salt water.   Other algae grew as long in saturated as in normal salt water.   Brown (2) found that *Enteromorpha intestinalis* can live in fresh water, but that *Prionitis, Rhodomela, Fucus, Nereocystis, Desmarestia, Laminaria* and *Cymathaere* die very quickly.   Cowles (5) mentions the ability of algae to adapt themselves to media of different strengths, noting specially the "accommodation" of *Mougeotia.*

The writer's experiments indicate that young *Nereocystis* plants are very tolerant of fresh water if the concentration of sea water be reduced very gradually.   Kelps varying in length from 3 to 14 cm. were fastened to stones by their holdfasts and placed in a tub which was set inside another a little larger into which water piped directly from the Sound was kept running continually.   This cooling bath kept the temperature of the water within $2°$ C. of that of the sea water.   A wheel attached to a water motor and arranged so as to revolve in the tub around a vertical axis kept the water constantly in motion.   The experiment was started on July 9, with the water 100 per cent salt; i. e., natural sea-water.   Every 24 hours the tub was entirely emptied and the salinity of the water decreased by 2.5 per cent of boiled fresh water.   By July 22 when the water was 30 per cent fresh, the kelps had all grown from .3 to .9 cm., depending on their original length.   Not until the water became 55 per cent fresh on August 3 did any of the kelps show signs of dying.   They all died when the percentage of fresh water reached 60 per cent.   However this limit is not considered conclusive because the fresh water used had an abnormally high organic content so that it often made the water in the tub appear quite brown.   The experiment shows that young kelps are able to adapt themselves to a considerable change in salinity.   To make this adjustment more evident, a young kelp was taken from its natural environment and placed directly in the tub containing water which was 60 per cent fresh.   At the end of twenty-four hours it was quite soft, and there

were large blisters on the fronds caused by the rapid intake of water into the cells.   The fact that no blisters were produced on the kelps for which the concentration of sea water had been very gradually reduced probably shows that a change in the osmotic pressure of the cells had occurred as a result of the change in the medium surrounding them.   However, it is just possible that the adjustment was metabolic, caused by the absence of chemical nutritive materials in the water.   An adaptation by means of the lowering of the concentration of the cell sap, which enables plants to live in water that kills those put directly into it, may be intimately concerned in the question of the ability of salt water plants to live in fresh water.

A fact which is of interest in connection with the growth of *Nereocystis* is that the stipe continues to grow for at least fifteen days after all the fronds are removed.   In most cases the rate of growth of kelps with the fronds cut off was somewhat slower than that of the controls, but sometimes elongation was just as rapid.   Unfortunately these experiments were started too late in the summer to determine how long the stipe can continue to grow without the fronds.   In only one case did removal of the fronds cause cessation of growth; and in no case was there a sign of death or decay.   This is contrary to the results obtained by Zeller (24), who found that plants with the fronds removed soon died.   Frye (12) found that loss of fronds causes a rise of pressure in the air cavity.

That the pressure of the sea water as well as light may limit the depth in which *Nereocystis* can grow is suggested by the relatively low pressure which the bulb can stand without collapsing.   To determine just what depth of water the pneumatocyst can stand without being crushed, a kelp was weighted with a large rock and lowered beneath the water by a long cord marked off into spaces of one meter each.   It was drawn up by means of a reel and examined for signs of collapse after each successive ten meter increase in depth; i. e., 1 kg. per sq. cm. increase in pressure. One of the three kelps experimented upon had the hollow part of the stipe crushed flat at a depth of 33 m. while the bulb remained unbroken.   The bulbs of the other two collapsed when they reached a depth of 50 m. This means that the bulb is able to resist an external pressure of 3 to 5 kg. per sq. cm.   This inability to resist stronger pressure suggests a possible reason other than darkness for the absence of *Nereocystis* in very deep water.   This would confirm the conclusion reached by Frye, Rigg, and Crandall (11) that the reports of enormously long kelps are exaggerated.

CONCLUSIONS

1. **Nereocystis luetkeana** grows longer in deep water than in shallow, indicating that growth is retarded when the surface is reached.

2. It also grows longer when deeply submerged than when floating on the surface attached to logs, or artifically attached to a raft.

3. Tension in the stipe as the result of mechanical stretching does not increase the rate of elongation.

4. Elongation of the stipe is more rapid when *Nereocystis* is in the dark than when it is in bright light. This accounts for the greater length attained by kelps in deep water; for the more rapid elongation of submerged kelps over those which are floating; and for the great length of kelps exposed to currents or tides, which, by their tendency to hold the stipe in a horizontal position, delay the time of reaching the surface and the consequent retardation of growth by strong light.

5. The short kelps growing in the rapidly flowing tide stream of the Argyle lagoon may find an explanation in the bright light to which they are subjected because of the shallowness of the water.

6. Less light penetrates rough water than smooth water, but whether the darkening thus produced in swift currents is sufficient to affect the rate of growth of *Nereocystis* has not been determined.

7. Aeration and motion of the water as a controlling factor of elongation finds support in the great length of the kelps in the currents of the San Juan Channel, but is refuted by the small size of those in the Argyle tide stream.

8. The stipe and fronds of *Nereocystis* are unable to live when encased in hoods which prevent the free access of water to the plant.

9. Young kelps are able to adapt themselves to the presence of at least 55% of fresh water in their environment if the change is gradual.

10. The stipe of *Nereocystis* continues to elongate at nearly normal rate for at least 15 days after all the fronds are removed.

11. The pneumatocyst can resist an external pressure of 3.3 to 5 kg. per square centimeter as shown by the fact that it does not collapse until sunken to a depth of 33 to 50 meters.

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Spirogyra gigantica, n. sp.

Grace A. Hill, University of Washington, Seattle.

Filaments 173 to 188 μ in diameter. Cells 1-2 diameters long, or slightly more or less. Chloroplasts not fewer than 4 and not more than 6, roughly parallel to each other, deviating from transverse by an angle of 10-25 degrees, making 1.5-3 turns in the cell, 15-22 μ wide, lobed at margin; pyrenoids conspicuous, 7-12 μ in diameter, 9-12 in each half-turn. Reproduction unknown.

So named on account of its large size. Collected by A. M. Hurd in basin of old fountain on University of Washington campus, Seattle, Wash., Nov., 1916.

It resembles *S. crassa* Kütz., but differs as follows:

A.   *S. crassa*—*Cells* 150-160 μ wide; chloroplasts .5-1 turn in the cell; pyrenoids 4-7 μ in diameter.

AA. *S. gigantica*—Cells 173-188 μ wide; chloroplasts 1.6-3 turns in the cell; pyrenoids 7-12 μ in diameter.
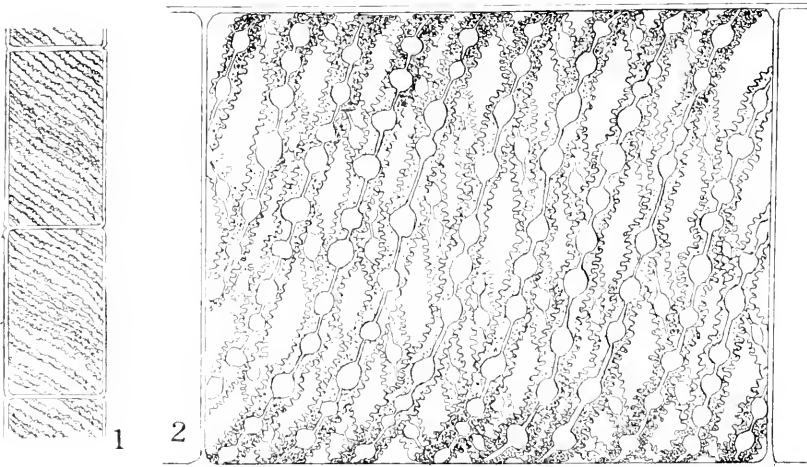
G. A. Hill, Del.   PLATE 33

Fig. 1. Cells about ready to divide. $\times$ 70.

Fig. 2. Cell recently divided, and thus short. $\times$ 328.

Distribution of Shore Algae on Shaw Island

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It has already been noted that the shores of the San Juan Islands are very rich in algal vegetation. Many species have been recorded but careful collecting constantly increases the list of marine algae found on these islands. A careful study of the distribution of the algae of each island would be required before this list may approximate completeness. This kind of a survey would not only be useful locally to those interested in investigations at the Puget Sound Marine Station, but would also be very desirable for gaining a general knowledge of the distribution of the species of the islands as compared with other localities. A careful study of distribution is also a prerequisite of many systematic problems of this locality. In a previous paper[1] the writer grouped the shore algae of San Juan Island into five associations as follows:

Endocladia association
Fucus association
Ulva association
Laminariaceae association
Zostera association

Since the general structure of the algal associations of Shaw Island and San Juan Island is not so very different, the above paper[1] may be used as a basis for the present paper. The purpose of this paper is to discuss the distribution of the shore algae of Shaw Island and to record such notes on distribution as may be helpful to investigators and collectors in this region.

Shaw Island is located east of San Juan Island. Its center is about latitude 48° 34′ and longtitude 122° 58′. It is separated from San Juan Island on the west by San Juan Channel; on the south and east from Lopez Island by Upright Channel; on the north from Orcas and Crane Islands by Harney Channel and Wasp Pass (*plate* 34). Shaw Island is the geographic center of the San Juan group. It is protected from the larger open bodies of water by other islands, but the tidal currents are very strong in some of the narrow channels about it.

In the present work several small islands that lie close to Shaw Island are included. Among these may be mentioned Canoe Island, off the south-

[1]Muenscher, Walter L. C. A Study of the Algal Associations of San Juan Island. Puget Sound Marine Station Pub. 1: 59-84. 1915.

east shore; and the Wasp Islands, a group of small islands and rocks off
the northwest shore.   With the exception of several bays and coves the
shore line of Shaw Island is very rocky.   Many reefs are found on the
south shore, while on the north shore almost vertical cliffs are very
common.
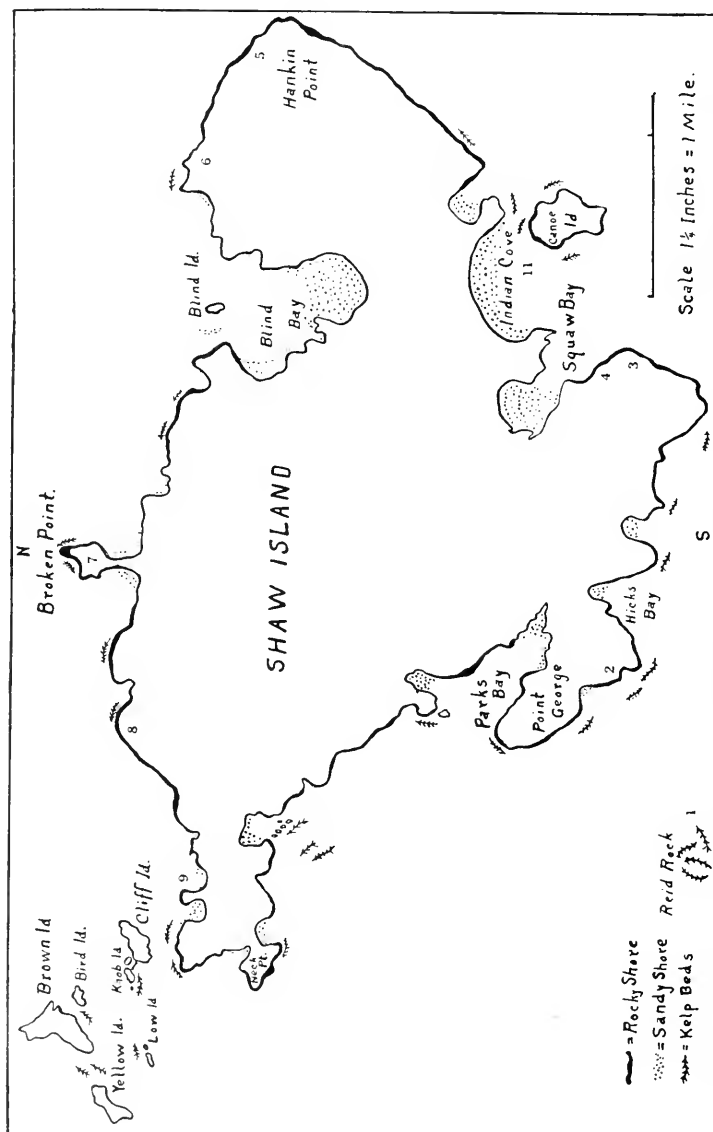
Map of Shaw Island and its smaller adjacent islands showing the irregular shore line, the character of the shore line, distribution of kelp beds and places referred to in this paper. (Base map after Coast and Geodetic Survey.)

PLATE 34

The five algal associations as they have been worked out on San Juan Island are also easily distinguished on Shaw Island. The structure of the associations may differ somewhat in some places: certain species may be more or less abundant. or sometimes some species drop out entirely. or different species may come in. However the zones are so similar to those described (*loc. cit.*) for San Juan Island that only a list of the six most common algae in each association will be given here:

1. *Endocladia association*

1. Endocladia muricata
2. Porphyra perforata
3. Gloiopeltis furcata
4. Enteromorpha linza
5. Enteromorpha intestinalis
6. Echellocystis sp.

2. *Fucus association*

1. Fucus evanescens
2. Gigartina mamillosa
3. Gloiopeltis furcata
4. Cladophora arcta
5. Microcladia borealis
6. Rhodomela larix

3. *Ulva association*

1. Ulva lactuca
2. Iridaea laminarioides
3. Enteromorpha linza
4. Hormiscia tetraciliata
5. Polysiphonia californica
6. Corallina officinalis

4. *Laminariaceae association*

1. Nereocystis luetkeana
2. Laminaria bullata
3. Laminaria saccharina
4. Costaria costata
5. Alaria tenuifolia
6. Agarum fimbriatum

5. *Zostera association*

1. Porphyra naiadum
2. Ulva lactuca
3. Enteromorpha linza
4. Agardhiella tenera
5. Laminaria saccharina
6. Iridaea laminarioides

While it is true that the above associations form rather distinct vertical zones in many places. this does not necessarily mean that they form distinct layers all around the island. On the contrary. these associations may be so modified in certain places that they are hardly distinguishable. The character of the shore line. and the presence of strong currents and exposure to sun. wind and waves. are responsible for many of the differences in algal vegetation in areas of relative vertical positions.

Where the shore is rock and the current is swift *Laminaria bullata, Alaria tenuifolia, Agarum fimbriatum* and *Desmarestia ligulata herbacea* abound in large numbers just below the low-tide mark. while farther out on the submerged rocks *Nereocystis luetkeana* is found. Rigg[2] charts beds of *Nereocystis* on the south and northwest ends of Shaw Island. *Nereocystis* beds on this island are mostly very narrow and close to the shore due to the abruptness of the shore in most places. The water soon becomes too deep for *Nereocystis* even near the shore. sometimes reaching a depth of 10 to 60 meters less than 100 meters from the shore[3]. The largest

[2]Rigg, Geo. B. Ecological and Economic Notes on Puget Sound Kelps: U. S. Senate Document No. 190. Washington. D. C. 1912.

[3]Coast and Geodetic Survey: Washington Sound. Washington. D. C. Jan., 1912.

kelp beds about Shaw Island are behind Canoe Island, near Broken Point, and on several large submerged rocks some distance from the shore. The largest of these rocks are: Reid Rock about midway between Shaw and San Juan Island, another one about 200 meters off the southeast end of Shaw Island and several others in a group southeast of Neck Point (*plate* 34).

Where the shore is muddy or sandy the algal vegetation becomes very different from that of the rocky shores. Here the Laminariaceae association disappears or is represented only by a few of its smaller members. This is apparently due to the inability of the larger species to find a place of permanent attachment on the sandy bottom. Eelgrass (*Zostera marina*) is very common in shallow sandy bays, where it forms a place of attachment for several smaller algae, especially *Porphyra naiadum*, which, together with the other algae which grow on shells and small stones among the eelgrass, form the common algae of the Zostera association. Rigg (*loc. cit.*) has already reported *Agarum* (*fimbriatum*) and *Laminaria* (*saccharina*) as being common on shells and stones on the sand and mud bottom of Blind Bay, Indian Cove and several smaller coves along the shore. *Agardhiella tenera, Costaria costata* and several species of *Pterosiphonia* and *Polysiphonia* are also found on shells and other objects where the bottom is sandy and clean. *Ulva lactuca* is the most common alga in the more quiet muddy places, into which it often drifts in large quantities, settling in beds sometimes even above the low tide line.

Reefs that are exposed to the wind and waves are usually quite barren when compared with the dense algal vegetation of the less exposed places. This is very prominent along the reefs of the south and southwest shores, on the rocks in Blind Bay and on Broken Point, all of which have a very sparse littoral vegetation. Some of these places have practically no *Fucus*, the few plants that are present are very small and appear as if they had been ground off by the action of the waves.

The north and west shores of the island are mostly very steep and covered with timber close to the shore line so that the shore algae are mostly in the shade at least in the afternoon. It is very striking to note the density of the algal vegetation on these shaded rocks when compared with similar places on the more barren sunny shores. In these shaded places *Fucus evanescens* crowds up to the upper limit of the Endocladia association, that is, clear up to the high tide line. *Rhodomela larix* grows to be 30 to 50 cm. long in the shade in the upper littoral zone; while ordinarily, in this region, it is a small seraggly plant 3 to 10 cm. long, growing in little tide pools. *Leathesia difformis, Soranthera ulvoidea, Microcladia borealis, Ptilota pectinata*, and several species of *Odonthalia* are

very abundant in the upper littoral zone; while *Codium dimorphum, Codium mucronatum, Colpomenia sinuosa, Apoglossum decipiens,* and *Griffithsia tasmanica* (?) are often found in the extreme lower littoral zone of these shaded rocky shores.

The algal vegetation on Canoe Island and on the Wasp Islands in general does not differ from that of Shaw Island. Nearly every species was found on each of the different islands (*table* 1). This probably indicates that the currents scatter the spores to all the shores; therefore if a certain alga is not found in a certain place it is probably due to unfavorable environment and not lack of distribution of spores.

TABLE 1. *Showing the number of species of algae found on Shaw Island and on the smaller islands around it.**

	Species common to each of 5 Wasp Islands.*	Species on Canoe Island.	Species common to 5 Wasp Islands and Canoe Island.	Species found on Canoe Island only.	Species found on Wasp Islands only.	Species found on Shaw Island only.	Total No. of species found on Shaw Island and its smaller islands	Species on San Juan Island.
Rhodophyceae	18	46	18	6	0	3	54	56
Phaeophyceae	17	23	16	4	0	8	31	30
Chlorophyceae	5	9	5	0	0	2	15	16
Myxophyceae	1	1	1	0	0	1	3	4
Total species	41	79	40	10	0	14	103	106

The following localities are of interest because in them are found certain algae, in great abundance. in exceptionally good condition, or species that are otherwise not common or even very rare. These places are indicated on the map by the numbers which precede them (*plate* 34).

1. Reid rock is a large submerged mass of rocks near the middle of San Juan Channel. It is marked by a buoy. but can easily be located by the large bed of *Nereocystis* growing upon it. The *Nereocystis* plants apparently grow on all of the rock that is less than about 15 meters below the surface. Numerous entire *Nereocystis* plants were removed from their place of attachment, the largest individual observed had a stipe 17 meters in length and blades 9 meters in length, making a total length of 28 meters. This bed contains the largest and healthiest individuals of *Nereocystis* that were observed among the San Juan Islands by the writer. The swiftness of the current and the depth of the water seem to be responsible for the excellent condition and immense size of these algae. Many smaller algae, such as *Polysiphonia urceolata, Desmarestia aculeata,*

*The 5 Wasp islands refer to Brown, Bird, Knob, Yellow and Cliff islands (plate 33).

Desmarestia ligulata herbacea, Nitophyllum latissimum, Callopyllis flabellulata, and others, are found on the holdfasts of these *Nereocystis* plants.

2.   Along the exposed rocky shore of the southwest side of **Point George,** *Bangia atropurpurea fuscopurpurea* and *Porphyra perforata* are very abundant in the middle and upper littoral zone.

3.   On the southwest headland of Squaw Bay are several small coves with gravelly beaches where *Hormiscia tetraciliata* is very common on large pebbles near the low tide line.

4.   About 100 meters back from point 3 on Squaw Bay, on a steep shady rocky slope, *Ptilota pectinata, Microcladia borealis, Soranthera ulvoidea, Leathesia difformis* and several species of *Odonthalia* were found very common in the littoral zone.

5.   Northwest of Hankin Point on the almost vertical rocks *Colpomenia sinuosa, Coilodesme bulligera* and *Scytosiphon lomentarius* were frequently found in the lower littoral zone during extremely low tides. Large specimens of *Rhodomela larix* were found here forming rather dense mats in the middle littoral zone.

6.   In a little cove east of Blind Bay (*plate 34*) *Agardhiella tenera* and *Polysiphonia urceolata* were found very abundant on shells and pebbles scattered over the sandy bottom at a depth of 1 to 2 meters.

7.   Broken Point is a steep rocky point projecting into the channel on the north side of Shaw Island (*plate 35*). Right on the point there is very little littoral vegetation and the kelp beds are very near the shore because the sides of the cliff are very steep. From just above the low-tide line to about 2 meters below it there is a very dense growth of *Iridaea laminarioides, Laminaria bullata, Alaria tennifolia, Costaria costata, Corallina officinalis, Amphiroa tuberculosa* and species of *Desmarestia*. On the overhanging and vertical rocks *Codium mucronatum* and *Codium dimorphum* were found in great masses.

8.   On this rock shore (*plate 34*) both species of *Codium* were found very common. In some spots *Codium* covered the rocks in the extreme lower littoral zone almost to the total exclusion of the other algae. *Porphyra nereocystis, Antithamnion floccosum* and *Ectocarpus confervoides* were often found growing on old kelp plants near this shore.

9.   On these low overhanging rocks *Apoglossum decipiens, Griffithsia tasmanica* (?) and *Codium dimorphum* were often found at or just below the extreme low-water mark.

10.   A small narrow cave was found just above the low-water mark on a limestone cliff on the north side of Cliff Island. The vertical rocks near the entrance to this cave were covered with dense mats of *Ectocarpus*

siliculosus, Griffithsia tasmanica (?), *Pylaiella littoralis*, and *Microcladia borealis.*

     11.   Indian Cove inside of Canoe Island (*plates* 34 and 36) is a small
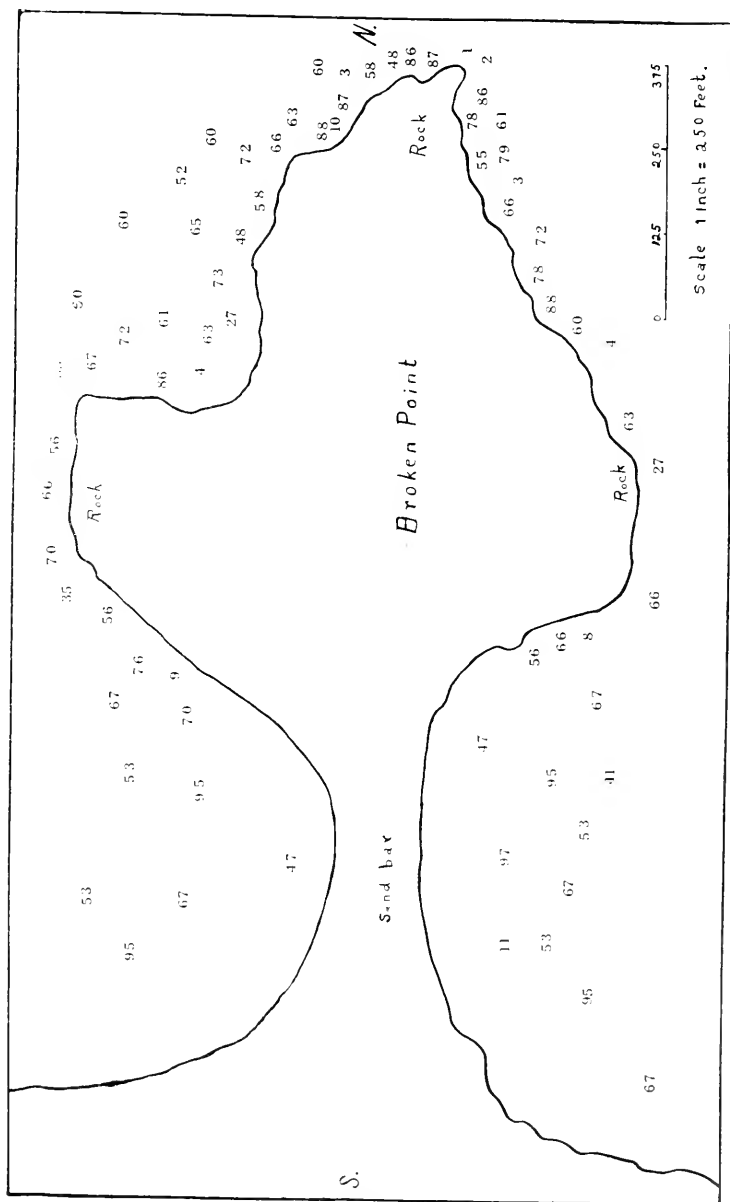
Map of Broken Point and vicinity showing the distribution of algae on the sandy and rocky shores. The algae to which the figures refer are given in a list beginning on page 207. See also page 199.

PLATE 35

body of water ranging in depth from 3 to 15 meters.   The bottom is most-
ly composed of sand, gravel and shells with some large rocks specially
on the east side.   The tidal currents between Shaw and Canoe islands
are strong, so that the water in this cove is well aerated and consequently
forms an excellent place for sublittoral algae.
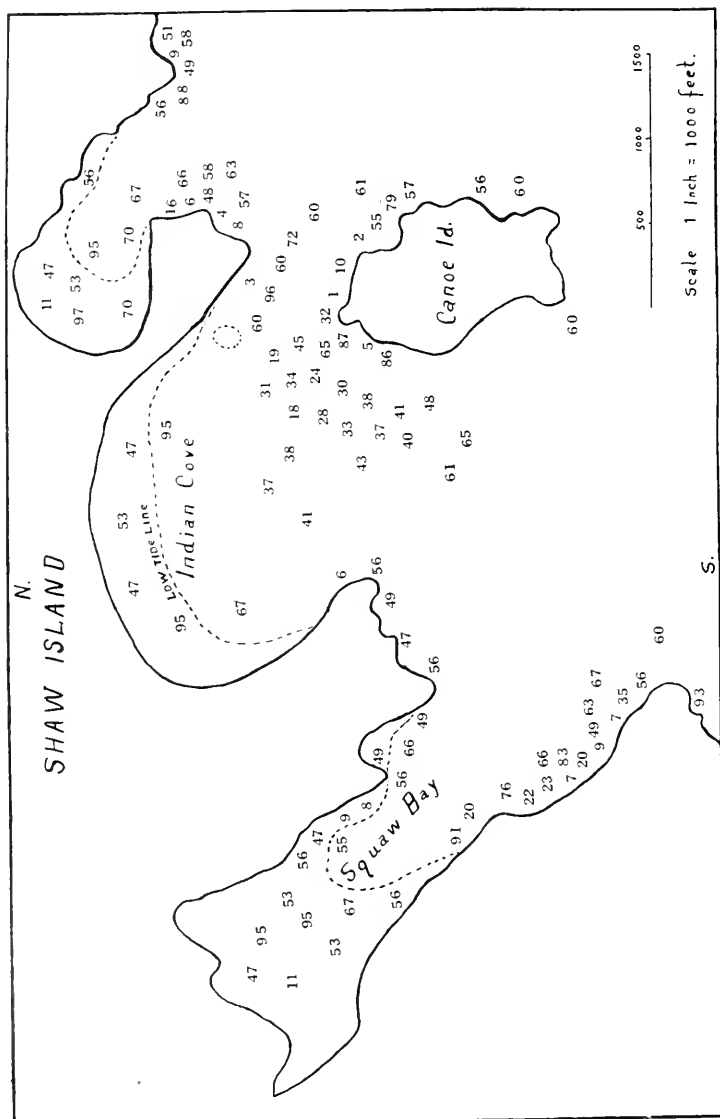
Map of Indian Cove and vicinity showing the distribution of algae. The algae to which the figures refer are given in a list beginning on page 207. See also page 205.

PLATE 36

Numerous hauls were made with a steam trawl in about 10 to 15 meters of water, thus bringing to the surface many species of plants and animals. Most of the algae of the deeper water were Rhodophyceae; only a few Phaeophyceae were dredged. The most common and abundant species in the deeper water were *Rhodymenia pertusa, Fauchea gardneri, Nitophyllum latissimum, Callophyllis flabellulata, Dasyopsis plumosa,* and *Agarum fimbriatum.* Most of these algae were found growing on old shells or on large pebbles. In the more shallow and rocky places the Phaeophyceae seemed to be much more abundant. The most common species in these places were *Laminaria bullata, Costaria costata, Agarum fimbriatum,* and *Nereocystis luetkeana. Cymathere triplicata, Laminaria complanata* and *Pleurophycus gardneri* were occasionally brought to the surface. Other algae found in Indian Cove and vicinity are indicated by figures on plate 36.

A LIST OF MARINE ALGAE FOUND ON SHAW ISLAND

The species are arranged according to their groups, from the highest to the least developed. The figure preceding each species refers to the figure by which it is indicated on the map (*plates 35* and *36*). The following abbreviations indicate in general where the algae were observed most frequently and also their relative abundance: ULI = upper littoral; L = littoral; LLI = lower littoral; SLI = sub-littoral; VA = very abundant; A = abundant; C = common; R = rare; VR = very rare; D = drifted ashore.

RHODOPHYCEAE

1. *Corallina officinalis* L.—LLI, A.
2. *Amphiroa tuberculosa* (P. and R.) Endl.—SLI, A.
3. *Constantinea rosa-marina* (Gmelin) P. and R.—SLI, C.
4. *Sarcophyllis californica* J. Agardh—SLI, C.
5. *Prionitis lyallii* Harvey—LI, R.
6. *Grateloupia cutleriae* (Binder) J. Agardh—LLI, R.
7. *Ptilota pectinata* (Gunner) Kjellm.—LI, R.
8. *Gloiopeltis furcata* (P. and R.) J. Agardh—ULI, VA.
9. *Microcladia borealis* Ruprecht—LI, A.
10. *Ceramium codicola* J. Agardh—LLI, C.
11. *Ceramium rubrum* (Hudson) Agardh—LLI, R.
12. *Ceramium californicum* J. Agardh—SLI, R.
13. *Platythamnion heteromorphum typicum* S. & G.—SLI, R.
14. *Antithamnion floccosum pacificum* (Harvey) S. & G.—SLI, C.
15. *Pleonosporium vancouverianum* J. Agardh—SLI, VR.

16. *Ceratothamnion pikeanum laxum* Setch. and Gard.—LLI, C.
17. *Griffithsia tasmanica?*—LLI, R.
18. *Dasyopsis plumosa* (Harvey and Bailey) Schmitz—SLI, C.
19. *Odonthalia semicostata* (Mertens) J. Agardh—LLI, R.
20. *Odonthalia aleutica* (Agardh) J. Agardh—LLI, A.
21. *Odonthalia lyallii* (Harvey) J. Agardh—SLI, C.
22. *Odonthalia floccosa* (Esper) Falkenberg—LLI, C.
23. *Rhodomela larix* (Turner) Agardh—LI, C.
24. *Pterosiphonia dendroidea* (Montagne) Falkenberg—SLI, C.
25. *Pterosiphonia arctica* (J. Agardh) Setch. and Gard.—SLI, C.
26. *Pterosiphonia bipinnata* (P. and R.) Falkenberg—LLI, C.
27. *Polysiphonia californica* Harvey—LLI, C.
28. *Polysiphonia urceolata* (Lightfoot) Greville—SLI, C.
29. *Polysiphonia atrorubescens* (Dillwyn) Greville?—LLI, R.
30. *Bonnemaisonia hamifera* Hariot—SLI, R.
31. *Apoglossum decipiens* J. Agardh—SLI, R.
32. *Nitophyllum ruprechtianum* J. Agardh—SLI, C.
33. *Nitophyllum latissimum* (Harvey) J. Agardh—SLI, C.
34. *Gracilaria confervoides* (L.) Greville—SLI, VR.
35. *Halosaccion glandiforme* (Gmelin) Ruprecht—LLI, C.
36. *Plocamium coccineum* (Hudson) Lyngbye—SLI, R.
37. *Rhodymenia pertusa* (P. and R.) J. Agardh—SLI, VA.
38. *Fauchea gardneri* Setchell—SLI, A.
39. *Fauchea fryeana* Setchell—SLI, R.
40. *Euthora fruticulosa* (Rupr.) J. Agardh—SLI, R.
41. *Agardhiella tenera* (J. Agardh) Schmitz—SLI, C.
42. *Anatheca furcata* Setchell and Gardner—SLI, R.
43. *Callymenia phyllophora* J. Agardh—SLI, C.
44. *Callophyllis furcata dissecta* Farlow—SLI, C.
45. *Callophyllis flabellulata* Harvey—SLI, A.
46. *Gigartina radula exasperata* (H. & B.) Setchell—SLI, C.
47. *Gigartina mamillosa* (G. & W.) J. Agardh—ULI, A.
48. *Iridaea laminarioides* Bory—LLI, VA.
49. *Endocladia muricata* (Harvey) J. Agardh—ULI, A.
50. *Porphyra miniata cuneiformis* Setchell and Hus—LLI, R.
51. *Porphyra perforata* J. Agardh—ULI, VA.
52. *Porphyra nereocystis* C. L. Anderson—SLI, C.
53. *Porphyra naiadum* C. L. Anderson—SLI, VA.
54. *Bangia atropurpurea fuscopurpurea* (Dill.) J. Agardh—ULI, C.

PHAEOPHYCEAE

55.   *Cystophyllum geminatum* (Agardh) J. Agardh—sLI, A.
56.   *Fucus evanescens* Agardh—LI, VA.
57.   *Alaria valida* Kjellman and Setchell—sLI, C.
58.   *Alaria tenuifolia* Setchell—sLI, A.
59.   *Egregia menziesii* (Turner) Areschoug—D.
60.   *Nereocystis luetkeana* (Mertens) P. and R.—sLI, VA.
61.   *Agarum fimbriatum* Harvey—sLI, A.
62.   *Agarum cribrosum* Bory—sLI, R.
63.   *Costaria costata* (Turner) Saunders—sLI, VA.
64.   *Pleurophycus gardneri* Setchell and Gardner—sLI, VR.
65.   *Cymathere triplicata* (P. and R.) J. Agardh—sLI, C.
66.   *Laminaria bullata* Kjellman—sLI, VA.
67.   *Laminaria saccharina* (L.) Lamouroux—sLI, A.
68.   *Laminaria complanata* Setchell and Gardner—sLI, R.
69.   *Chordaria abietina* Ruprecht—LLI, R.
70.   *Leathesia difformis* (L.L Areschoug—LI, C.
71.   *Desmarestia ligulata* (Lightfoot) Lamouroux—sLI, R.
72.   *Desmarestia ligulata herbacea* (Turner) J. Agardh—sLI, A.
73.   *Desmarestia aculeata* (L.) Lamouroux—sLI, C.
74.   *Desmarestia aculeata media* (Agardh) J. Agardh—sLI, C.
75.   *Desmarestia viridis* (Mueller) Lamouroux—sLI, R.
76.   *Soranthera ulvoidea* Postels and Ruprecht—LLI, C.
77.   *Scytosiphon lomentarius* (Lyngbye) J. Agardh—LLI, VR.
78.   *Colpomenia sinuosa* (Roth) Derbes and Solier—LLI, R.
79.   *Coilodesme californica* (Ruprecht) Kjellman—sLI, C.
80.   *Coilodesme bulligera* Stroemfelt—LLI, R.
81.   *Ectocarpus siliculosus typicus* Kjellman—LLI, R.
82.   *Ectocarpus confervoides* (Roth) Le Jolis—sLI, C.
83.   *Pylaiella littoralis* (L.) Kjellman—LI, R.
84.   *Phycocelis baltica* (Reinke) DeToni?—sLI, C.
85.   *Ralfsia verrucosa* (Areschoug) J. Agardh—LI, A.

CHLOROPHYCEAE

86.   *Codium mucronatum* J. G. Agardh—LLI, C.
87.   *Codium dimorphum* Svedelius—LLI, C.
88.   *Cladophora arcta* (Dillwyn) Kützing—LLI, C.
89.   *Cladophora scopaeformis* (Ruprecht) Harvey—LLI, R.
90.   *Cladophora spinescens* Kützing)—LLI, C.
91.   *Rhizoclonium riparium implexum* (Dillwyn) Rosenvinge—LI, C.

92.   *Chaetomorpha* sp.—ULI, R.
93.   *Hormiscia tetraciliata* Frye and Zeller—LLI, C.
94.   *Ecbellocystis* sp.—ULI, C.
95.   *Ulva lactuca* L.—LLI, VA.
96.   *Enteromorpha linza* (L.) J. Agardh—LLI, VA.
97.   *Enteromorpha intestinalis* (L.) Link—LI, C.
98.   *Enteromorpha clathrata* (Roth) Greville—LI, R.
99.   *Enteromorpha prolifera* (Fl. Dan.) J. G. Agardh—LI, C.
100. *Chlorochytrium inclusum* Kjellman—SLI, C.

MYXOPHYCEAE

101. *Dermocarpa fucicola* Saunders—LI, C.
102. *Calothrix crustacea* Thur.—ULI, R.
103. *Anabaena variabilis* Kützing—ULI, R.

SUMMARY

1.   In general the shore algae of Shaw Island are not very different from those of San Juan Island in distribution nor in the number of species represented. Of the 12 species that were not found on both islands 2 were found only on Shaw Island, and 10 were found only on San Juan Island. Of the latter, the 2 most important species are *Egregia menziesii* and *Hedopyllum sessile*, which grow only on the rougher shores.

2.   The algae of Shaw Island are also well distributed on the shores of the smaller islands around it (*table* 1). This seems to indicate for most of the species, many spores efficiently scattered by waves and currents.

3.   The structure of algal vegetation occupying relative positions above or below the low-tide line is greatly modified by the character of most of the species, many spores efficiently scattered by the waves and currents.

4.   The absence of certain species of algae from certain shores on Shaw Island and San Juan Island is usually due not to lack of distribution but to unfavorable environment.

The writer is indebted to various members of the Algology class of the Puget Sound Marine Station for assistance in making simultaneous observations on different shores during favorable tides.

Codium dimorphum

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Codium dimorphum and *C. mucronatum* are probably the only repre-
sentatives of the genus found in Puget Sound. *C. dimorphum* has been
reported from San Juan Island as *C. adhaerens* (10). As pointed out
by Svedelius (12) the two species differ in that the former is not tomen-
tose and is characterized by having two types of utricles. The presence
of trichomes is not mentioned in the original description of *C. adhaerens*
(1). Svedelius, however, in a letter to the writer, reports that as the
result of careful inquiry he has found that the original material of C. A.
Agardh (1) is identical with that of J. G. Agardh (2), who says that the
utricles are always tomentose and does not mention the presence of two
kinds of end walls on the utricles. The latter character and the absence
of trichomes is the basis for Svedelius' new species. *C. dimorphum* (12).
Comparison of a specimen of Svedelius' material with the Puget Sound
species showed that the two are identical. If Svedelius is justified for
the reasons given above in splitting a new species from *C. adhaerens,* we
must conclude that our species falls under *C. dimorphum.*

    C. dimorphum grows on rocks in the most exposed places in the lower
littoral zone. The less protected the habitat, the firmer and more vig-
orous are the plants. Individuals are often abundant on a single rock,
yet not found anywhere else in the locality, showing that this species is
not fitted for wide distribution. It was noticed that it was most fre-
quently found on the under side of overhanging ledges. Hauck (7) and
Falkenberg (6) have reported the same fact for *C. adhaerens.* Berthold
(3) found this, as well as other species of *Codium*, growing only in shaded
places, on the under side of overhanging rocks, or where the water was so
muddy as to protect the plants from direct sunlight. He says that the
effect of strong light is such that the plants tide over the summer and
reproduce only in winter and spring. Küster (9), however, did not find
that *Codium* grew any more commonly or any differently in shaded places
than in brightly lighted ones. Other than that the plants were on the
under side of rocks more commonly than on the upper, no preference for
dimly lighted places was noted.

    The plant body consists of a dark-green flattened thallus, irregular in

shape, with a round-lobed margin. It adheres tightly to the rock on which it grows, sometimes attached only at a small central area, the lobes being free. The more vigorous specimens are firm and have a smooth velvety surface, but many plants are spongy and soft. The thallus rarely exceeds 1 cm. in thickness and usually covers an area of about 20 sq. cm. The lobes are often nearly separate from the rest of the plant, sometimes attached to it by only a few filaments. This vegetative multiplication is shown in figure 1 of plate 16 in Svedelius' (12) paper.

The thallus is made up of pith filaments ending in utricles, which are perpendicular to the surface and held tightly together by a gelatinous substance so that they form a compact cortex. The individual pith-filaments are expanded at their lower ends to form lobed holdfasts, which are sometimes clear and sometimes densely green (*Fig.* 7).

The pith-filaments are slender threads, almost colorless, 12 to 30μ in diameter, rarely as wide as 45μ, with one or more utricles at the upper end and a holdfast at the other (*Fig.* 6). One filament was measured which was 10.3 mm. from the holdfast to the tip of the utricle, and which had no branches or any visible connection with the rest of the plant. In many respects the plant body of *C. dimorphum* resembles the holdfast cushion of *C. mucronatum*. It has the same general shape, the same lobed margin, the same internal structure. It seems probable that *C. mucronatum* has been derived from a form like *C. dimorphum*. If this be the case, the erect fronds of the former are specialized structures for bearing the reproducing utricles.

The pith-filaments of *C. dimorphum* are usually without either cross-walls or plugs. Very rarely thin partitions resembling cross-walls are present in a filament; and one plug-like thickening was found, but its structure was not clear and it did not look exactly like the true plugs of *C. mucronatum* (*Fig.* 13). A plug is commonly present, however, in the base of each gametangium and of each lateral branch of the utricle (*Figs.* 2-4). This absence of plugs in the filaments of a species which grows horizontally appressed to the rocks, and hence has comparatively short filaments, may indicate their function. It is obvious that the necessity for cross-walls to hold the cell contents in place does not exist in these filaments to the extent that it does in the long soft fronds of *C. mucronatum*.

The mature utricles of *C. dimorphum* are 75-100μ in diameter. Occasionally a very old one is considerably swollen a short distance from the outer end, and its diameter at the widest part may be as much as 250μ (*Fig.* 2). The utricles are cylindrical, truncate, and slightly thick-walled at the tip. They are more or less constricted about 225μ from the end. Usually they are somewhat enlarged just below this constriction so that

the widest part of a utricle is often about 300μ from the tip (*Figs. 3-5*). They taper gradually back to the size of the pith-filament and are not cut off by plugs; therefore unless the utricle is a lateral branch, its lower end is indefinite and its length cannot be measured.

Unlike the utricles of *C. mucronatum*, those of *C. dimorphum* branch in a very characteristic manner (*Figs. 2, 3*). A young branch starts as a protrusion of the utricle and grows upward. Before long a plug forms in the base and the young utricle bulges downward below the place of attachment. This bulge elongates at a more rapid rate than the utricle above, and forms a long "dangling" pith-filament several millimeters in length. These new pith-filaments and utricles remain attached to the old one, and when the former reaches the surface of the rock on which the plant is growing it probably forms a holdfast (*Fig. 6*). In preparing slides for microscopic examination the attachment is often broken so that filaments are found with the lower end rounded and not expanded into a holdfast, and which can be traced to the terminal utricle without finding any apparent connection with the rest of the plant (*Fig. 5*). There does not seem to be any constant number of branches. One utricle was found with six branches and at least eleven scars where other filaments had been broken off.

The young utricles taper at the end and have hard thickened tips. As they grow older the diameter increases and the end becomes truncate. After reaching a certain size, 75-110μ, the tip ceases to increase in diameter and enlarges 225-300μ back from the end. The oldest utricles are very large, sometimes without chlorophyll, and often collapsed at the end.

The end walls of the utricles may be thin, or characteristically thickened. They may be as much as 300μ thick, and when thick are distinctly striated, as if formed in layers. This "dimorphism" is one of the points upon which Svedelius (12) bases this species. However, some plants are found without any thick end walls, and others have only the thick walled type; but quite often the utricles of the upper surface are thin walled, while those on the under side of the lobes and around the margin of the thallus are thick walled. Although observations are rather limited, it seems to be the case that the plants of the more exposed localities have the thicker walls.

It is not unusual in this species to find one utricle growing from the tip of another. In fact, this may occur three or four times in succession, so that a structure like that shown in Fig. 8 is quite often seen. The utricles occasionally divide dichotomously at the tip (*Fig. 12*). They are also sometimes found with a slender pith-filament growing from the end, which might later develop a terminal utricle (*Fig. 11*).

The absence of utricle hairs is one of the characters separating this species from *C. adhaerens.* Agardh (2) describes the latter species as always tomentose. Oltmanns (11) points out that the growth of trichomes is periodic; but if they occurred in *C. dimorphum* at some other season than that in which Svedelius and the writer have studied the plant, scars would be left as in *C. tomentosum* (9) and *C. mucronatum* (8). Since the scars are not found in our species it is practically certain that the plant is never tomentose.

The same questions arise in the study of this species that were encountered in the study of *C. mucronatum* (8); viz., whether the reproduction is sexual as commonly described for this genus, or whether the reproductive bodies found are asexual spores; whether, in case reproduction is sexual, the gametes are alike or unlike. The difficulty arises from the fact that only one kind of gametangium was found, and they all contained the same kind of gametes or zoospores so far as could be detected. These gametes (?) are borne in slender ovate gametangia, usually 300μ long and 50μ in diameter. They are lateral branches of the utricle arising about 500μ from its end (*Fig.* 4); there are, however, frequent exceptions to this, specially when there are two or three on the same utricle but originating at different levels. When two gametangia occur on the same utricle of *C. mucronatum,* they are equally distant from the end as a rule (8), but this is not the case in *C. dimorphum.* In the latter they appear at considerable distances from each other and sometimes are scattered along the utricle without any definite order.

All of the utricles on a plant do not bear gametangia at the same time. In some spots on the thallus nearly every utricle will have one, while in another area near by there will be none. Gametangia are more abundant in centrally located areas than on the margin; but they are occasionally found in the latter position, though rarely on the under side of the lobes. Svedelius says that the inner thin-walled utricles bear the gametangia, while the outer thick-walled ones produce branches which are homologous to gametangia. However, the writer has commonly found gametangia on these branches and on the utricles with the thick end wells. Therefore Svedelius' inference of a physiological dimorphism is not justified.

The young gametangium is first a rounded knob caused by the protrusion of the utricle wall. It elongates and becomes densely filled with the protoplasm and chlorophyll that is pushed up into it (*Fig.* 1). A thick plug develops at the base, and the contents round up into a dark green granular mass (*Fig.* 4). When mature this mass breaks up into round bright-green gametes (*Fig.* 10).

Although no specific reference to male gametes in *C. dimorphum* has been found, Collins (4), Wille (15), Ernst (5), and Oltmanns (11) describe them for the genus *Codium*. They claim these gametes are formed in gametangia with yellowish contents and are very much smaller than the female gametes. Thuret (13) and Hauck (7) refer to zoospores in this genus, and Went (14) found pathenogenesis. In case there are male gametes in this species, those described in this paper are the female gametes on account of their relatively large size. It is quite possible that these are parthenogenetic. This would explain the rarity of male gametes; or it may be that the two kinds of gametes are produced at a different season, in which case those found in late summer may be parthenogenetic or asexual or functionless.

A translation of Svedelius' (12) description of *Codium dimorphum* reads as follows: "The whole thallus divided into unequal lobes, expanded above the substratum and adhering to it, about 5 mm. thick, cushion-like, smooth, dark green, margins of the lobes pale, lobes either just loosely held together or separated, hairs wanting; utricles of the exterior stratum about 50μ thick, of two kinds; that is to say, on the margin of the lobes they are cylindric-clavate to obovate-clavate, apex blunt and either very much thickened or with a convex half-moon shaped callus, chloroplasts and sporangia sometimes wanting, lower part more slender and showing scarcely any difference in diameter from the threads of the interior stratum; [the second kind with] apex slightly thickened so that there is almost no protection through thickening of the membrane, chloroplasts numerous and sporangia present; sporangia about 40μ thick, 6 times as long as wide."

In order to make the description of the plant more complete, the following is suggested as embodying Svedelius' conception of it together with certain other facts. It is specially desired to take the emphasis from the dimorphism of the utricles in view of the fact that some plants have only the thin-walled type while in others the thick-walled ones predominate, not only "on the margin of the lobes" but all over the plant. Furthermore, sporangia are frequently found on the thick-walled kind and on their branches, in spite of the fact that Svedelius considers these branches the homologues of the sporangia of the thin-walled type:

Codium dimorphum Svedelius, Svenska exped. t. Magellansländerna 3: 300-304, 1900. Plant body dark green, irregularly lobed, cushion-like, spongy in texture; rarely more than 1 cm. thick, often deeply lobed; pith-filaments 12-30μ in diameter, with holdfast at base and utricle at upper end; utricles 50-100μ in diameter, cylindrical, truncate, often slightly constricted just back from the tip, branching to form new filaments; end wall of

utricles unmodified or characteristically thickened and striated; trichomes wanting; plugs present only in base of gametangia and at origin of utricle branches; gametes (?) round, bright green, many; gametangia slender, ovate, 300μ long, $40\text{-}50\mu$ in diameter.

CONCLUSIONS

1.   The *C. adhaerens* (Cabr.) Agardh reported from San Juan Island, and probably that from all of Puget Sound, is *C. dimorphum* Sved. in view of the fact that it has no utricle hairs and possesses two types of utricles, the one with unmodified end wall, the other with thickened striated end wall.

2.   The thick-walled type may predominate all over the thallus, or it may be found only around the margin and on the under side of the lobes, or it may be wanting entirely.

3.   This variation in the thickness of the end wall of the utricles is probably due to differences in environment.   That this dimorphism of the utricles is probably not a physiological dimorphum is indicated by the fact that gametangia have been found quite commonly on the thick-walled type and on their branches.

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PLATE 37

(All drawings made with camera lucida except Figs. 8 and 9.)

1. Utricle with young gametangium. × 75.

2. Old utricle with branches, two of them beginning to grow downward. × 75.

3. Utricle with branches, one showing how a new filament may develop. × 75.

4. Utricle and gametangium. × 75.

5. Upper and lower ends of a filament developed from one like Fig. 3; not yet attached. × 75.

6. Filament with holdfast. × 75.

7. Holdfast, the lower end of a filament. × 75.

8. An unusual structure showing how utricles develop from the tips of the older ones. × 75.

9. Tip of utricle with thick end-wall. × 75.

10. Gametangium with gametes. × 325.

11. Utricle with filament growing from tip. × 75.

12. Utricle branching dichotomously. × 75.

13. Two lateral utricles. × 75.
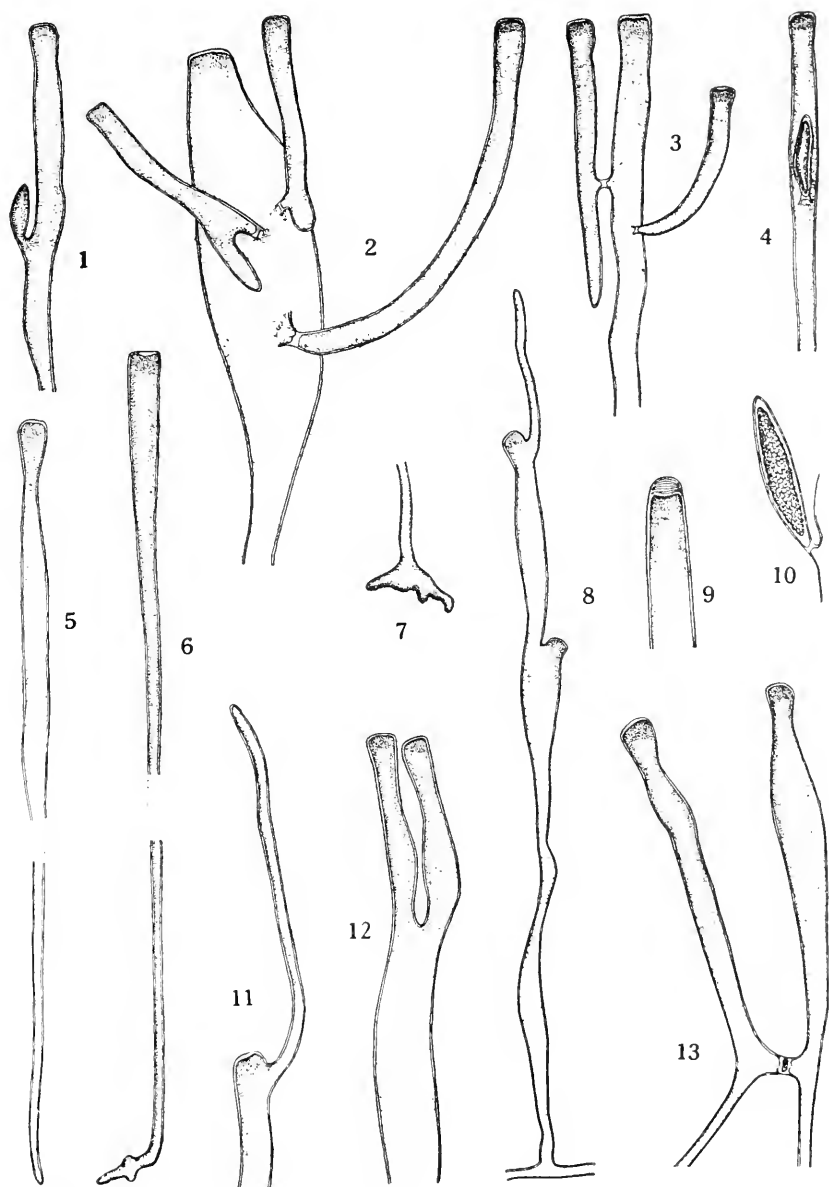
Conferva bombycina Agardh in Washington

Grace A. Hill, University of Washington, Seattle.

Forming a yellowish or a whitish floccose mass; filaments 6-11 μ in diameter, cells cylindrical or somewhat inflated, 2-4 diameters long; cell wall thin; chloroplasts small or of moderate size, several in the cell.— Collected by T. C. Frye in a roadside ditch at Fauntleroy, Seattle, Wash., Dec., 1916.

The plants examined differed from the above in that the diameter was 8-12 μ, and the length of the cells 2-5 diameters. The color of the mass, too, might better be described as faded green. Wolle mentions the shrinkage of alternate cells in dying (*Fig.* 2 below); also the irregular thickness of the filaments, which the writer's observation's confirm.
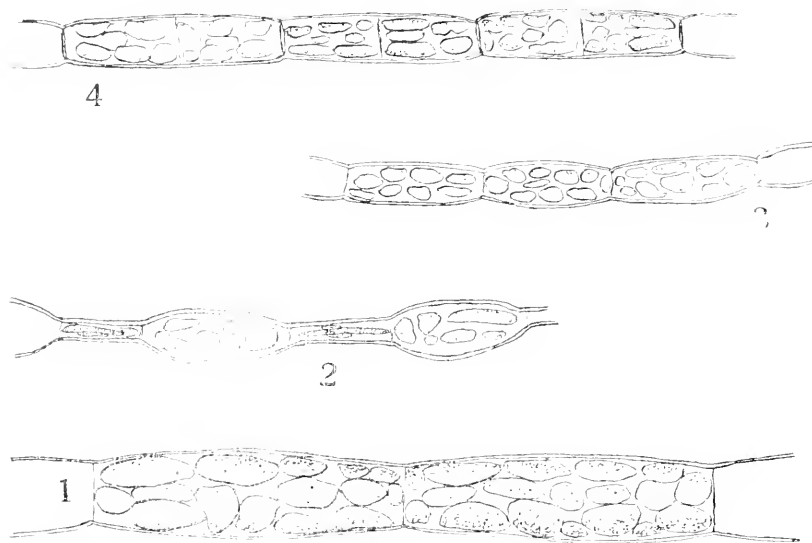
G. A. Hill, Del.   PLATE 38

Fig. 1.   Part of filament showing characteristic inflation of cells. $\times$ 1104.

Fig. 2.   Part of filament showing peculiar alternate shrinkage. $\times$ 550.

Fig. 3.   Part of filament. $\times$ 450.

Fig. 4.   Part of filament showing cells dividing. $\times$ 550.

Chytridium alarium on Alaria fistulosa

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While preparing slides for a paper on *Alaria fistulosa*, certain structures not to be accounted for as necessary parts of the alga were observed. They appeared in various forms in all parts of the plant except the heavy, older portion of the stipe. At that time a consideration of them was deferred until the paper in hand was completed. It seemed certain, however, that the bodies represented a fungus parasitic on *Alaria fistulosa*. This paper traces the life history of this fungus, *Chytridium*, so far as it could be determined from preserved material. Fresh material, and well killed material, were greatly needed; but the opportunities for getting them seemed too distant to withhold publication longer.

Examination of all of the species of brown algae readily available at the Marine Station at Friday Harbor showed no trace of this fungus in any of them. *Alaria valida*, from Alaskan waters, was also examined, but it was not infected. It was found in every specimen of *A. fistulosa* examined. The fungus is least abundant in the stipe, appearing only at its upper end, and scantily there. It grows scantily in the angle where the thin part of the blade joins the midrib. It is more abundant in the older portions of the midrib than in the growing region. It is abundant in the thin portion of the blade but does not commonly maintain its normal shape there, being more nearly globular, or even flattened parallel to the surface. In the sporophylls it attains its best development. Probably this is due to the pellicle above the sporangia of the host tending to protect the fungal sporangium. The sporangia and paraphyses are readily pushed aside by the fungus, and give space in which the sporangium of the parasite may expand. The parasite readily pushes its way through the pellicle when the spores are about to be discharged. The spores probably become motile before they enter the host plant.

The materials sectioned were collected by Dr. T. C. Frye and Dr. G. B. Rigg, on the United States Bureau of Soils Kelp Investigation Expeditions to Alaska in 1913. It was killed and preserved in two percent formaldehyde. The best stain was erythrosin, but safranin proved fairly successful. Good material for drawings was secured by allowing slides to stand for some time in alcohol which had been used to draw safranin stain. In this way the host was lightly stained, while the fungus retained its characteristic yellowish to brownish color. Heavy stains are wholly

unsuccessful, because they are taken readily by the heavy membranous wall surrounding the fungus, and are not readily drawn from it.   The spores themselves stain slowly and destain quickly.   The granular appearance of the spores within the sporangia (*Fig.* 6) was best observed in freehand sections quickly dehydrated, stained with erythrosin, and mounted in balsam.   During the process of dehydration and infiltration to make paraffin blocks, many of the sporangia were broken off, since they protruded through the pellicle.   In freehand sections more of them remained intact.

The life history could be clearly traced with the exception of that portion spent outside its host, probably as a free-swimming zoospore.   In the earliest stages of its development found (*Fig.* 1) it was a small spherical body, with a heavy membrane surrounding it.   A little later (*Fig.* 2) it showed considerable elongation, with the long axis perpendicular to the surface of the host.   The host cell containing the fungus elongates at the same time, sometimes reaching many times its original length.   The cell may be wholly filled by the fungus but more frequently it is not.   The parasitic body thru growth becomes oval, then oblong, then cylindric. Later the outer end is drawn out to resemble a neck or finger-like projection of the more deeply imbedded body of the parasite.   The contents of the membranous bag is forced outward, thru the narrow finger, enlarging the tip under the pellicle (*Figs.* 3-4).   The outer swelling becomes the sporangium.   It elongates rapidly and the walls of the imbedded portion contract, forcing the contents outward into the sporangium.   During its development the sporangium forces its way to the surface, becoming epiphytic (*Figs.* 5, 6).   If the sporangium is not too long it may stand erect, but more commonly it turns to one side like the bowl of a pipe (*Fig.* 5).   That portion of the membranous covering within the host then shrivels up slowly, or becomes perforated with holes, and seems to be disintegrating.   In the older portions of the midribs examined the sporangia were empty and deteriorating rapidly.

In the early stages of development of the fungus no rhizoids are found (*Figs.* 1-4), but as the fungus approaches maturity blunt rhizoids are sent out between host cells, or even project into the sides of adjacent cells, pressing in their sides, but not penetrating the walls (*Figs.* 5-10). In some cases rhizoid-like structures are sparingly developed, while in others they are sufficiently numerous to make the surface of the endophytic portion of the fungus quite rough.

In a previous paper the writer (6) described papillate bodies on the surface of the sporophylls of *Alaria fistulosa*.   An hypothesis there advanced as to one cause of these elevations was that the outer portions of the sporangia of the alga crowded one another and compelled the tissues to rise, thus giving greater surface for the fruiting layer.   Another cause

appears to be the additional over-crowding of the fruiting layer, due to the great number of fungus sporangia. Both host and parasite have sporangia which are small at the base and broad at their outer ends (*Fig. 5*).

Comparatively few parasitic fungi having marine algae as hosts have been described. Lemmerman (7) names only one marine form, *Dothidella laminariae,* a Pyrenomycete, although he names 192 species parasitic on fresh water algae. Estee (2) describes another Pyrenomycete which she calls *Guignardia irritans,* parasitic on *Cystoseira osmundacea* and *Halidrys dioica.* Patouillard (8) describes *Zignoella calospora* parasitic on *Castagnea chordariaeformis.* Patouillard and Hariot (9) found *Zignoella enormis* on *Stypocaulon scoparium.* Jones (5) found *Sphaerella chondri,* a fungus similar to *Guignardia irritans,* on *Chondrus crispus.* Southerland (11, 12, 13) has found several Pyrenomycetes parasitic on marine algae. Reed (10) describes two ascomycetes, *Guignardia ulvae* on Ulva, and *Guignardia alaskana* on *Prasiola.* Griggs' (4) figures of *Phodochytrium* suggest the fungus on *Alaria* somewhat, but in *Rhodochytrium* the spores are formed endophytically.

Of the Phycomycetes several species are known on marine algae. Cohn (1) describes *Chytridum polysiphoniae* on *Polysiphonia violacea, Olpidium (Chytridium) plumulae* on *Antithamnion plumula,* and *Olpidium (Chytridium) entosphaericum* on *Bagnia fusco-purpurea* and *Hormiscia penicilliformis.* Fisher (3) also cites in literature not available *Rhizophidium dicksonii* on *Ectocarpus, Olpidium sphacellarum* on *Sphacelaria* and *Cladostephus, Olpidium tumaefaciens* on *Ceramium, Olpidium bryopsidis* on *Bryopsis plumosa,* and *Olpidium aggregatum* on *Cladophora.*

Thus there are reported as growing on marine algae so far as the writer could find several Phycomycetes, among which is one *Chytridium;* a considerable number of Ascomycetes, most of which are Pyrenomycetes; and no Basidiomycetes.

A search of the available literature failed to disclose any species to which this plant could be referred. However, its life history, so far as it could be studied with the available material, seems to refer it to the genus *Chytridium.* Since it grows parasitic on *Alaria,* it is named as follows:

CHYTRIDIUM ALARIUM sp. nov. Vegetative portion of the fungus intracellular, spherical at first, becoming oblong, without hyphae, sometimes with short rhizoids which press in between the cells and into the walls of the host but do not pierce them, otherwise unbranched. Sporangium oblong, about 75μ long and 20-25μ in diameter, smooth, brown. Spores (probably 300 spores but cilia not seen) 3-4μ in diameter, spherical or nearly so. Sexual reproduction unknown. Parasitic on *Alaria fistulosa.*

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PLATE 39

Fig. 1.   Earliest stages of fungal development. showing enlarged host cells containing fungi. $\times$ 360.

Fig. 2.   Later stage. showing radial elongation of host cell and fungus. $\times$ 425.

Fig. 3.   Fungus with outer end elongating to form sporangium; *s,* sporangia of host surrounding it; *p,* pellicle of the host over it; *r,* paraphysis. $\times$ 360.

Fig. 4.   Sporangial portion of fungus about to pierce pellicle. $\times$ 360.

Fig. 5.   Sporangium after piercing pellicle: *f,* fungal sporangium. $\times$ 360.

Fig. 6.   Mature sporangium with spores about to be discharged. $\times$ 360.
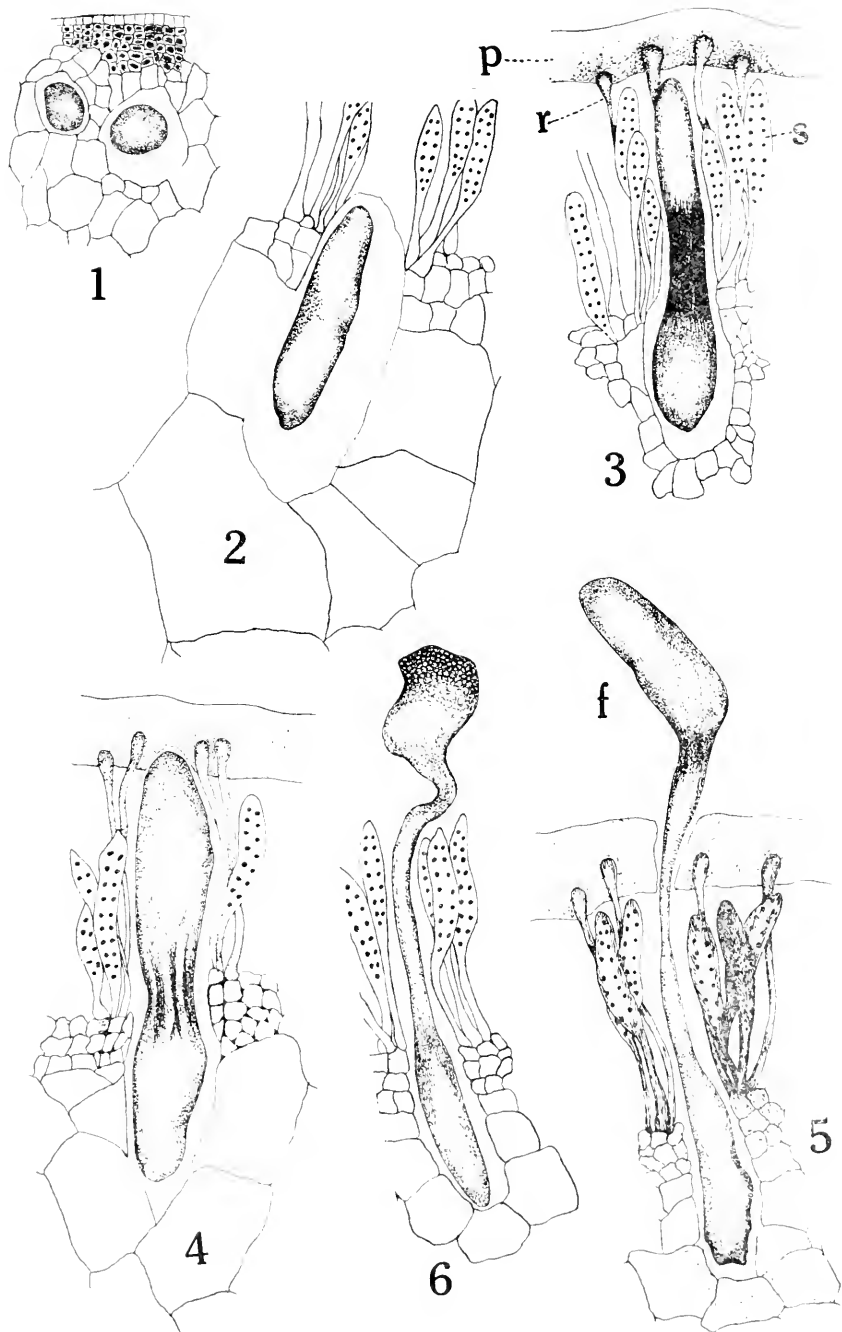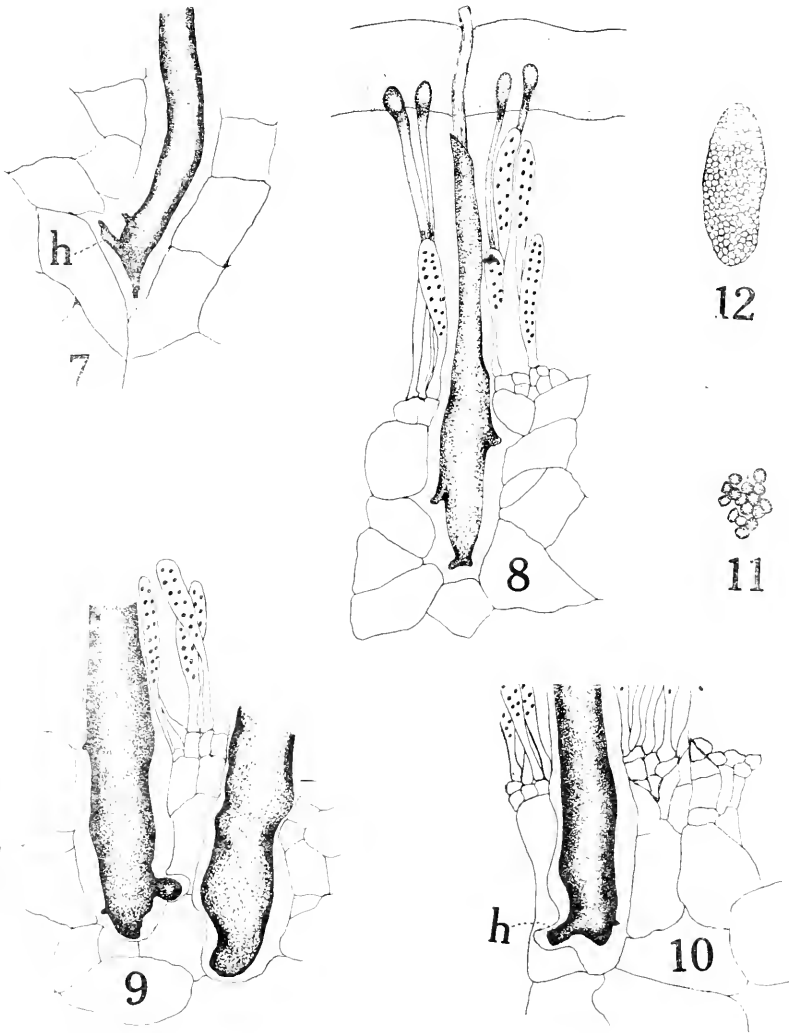
A. L. Kibbe, Del.   PLATE 10

Figs. 7, 8.   Rhizoids extending between cells; *h*, rhizoids.   × 360.

Figs. 9, 10.   Rhizoids pressing in walls of host cells; *h*, rhizoids.
× 360.

Fig. 11.   Spores of fungus.   × 550.

Fig. 12.   Fungal membrane enclosing spores of fungus.   × 360.

Micrometabolism of Nereocystis

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The purpose of this paper was to determine to what extent light can be thrown on the problems·of metabolism in the plant by means of reactions, the results of which are viewed under the microscope. This method of investigation, as indicated in the titles of the books by Tunmann[1] and by Molisch,[2] is usually called microchemistry. Micrometabolism perhaps better expresses the point of view from which this present investigation was undertaken. *Nereocystis luetkeana* was chosen on account of the attention that kelp beds have been given economically, and because no previous work of this nature has been done on it. The present paper deals only with the inorganic constituents of the cell and the composition of the cell wall.

INORGANIC CONSTITUENTS

Many chemical analyses have been made of the kelps of the Pacific Coast. Balch[3] was the first to call attention to the large quantities of potassium and iodine. Later Stewart[4] made a detailed inorganic analysis and with the exception of iodine found them to contain the same elements as other plants, differing only in the percentages. His table of analyses was made the basis of this work on the inorganic constituents. He found the composition of the ash of the harvestable portions of *Nereocystis* to be as follows: Ca, 2.10%; Mg. 1.55%; Na, 11.05%; K, 33.66%; $Fe_2O_3+Al_2O_3$, .17%; Cl. 40.89%; SO_4, 4.63%; CO_3, 3.10%; PO_4, 1.91%. Analyses made by Turrentine[5] showed .12% iodine in the fronds and .15% in the stipe.

The methods used in this inorganic analysis were in general those suggested by Tunmann[1] and Molisch[2] with a few modifications. Sections about 9 μ thick were taken of the holdfast. stipe and fronds, and washed in distilled water to remove any sea water or cell contents that might be on the surface of the sections. With the exception of the test for iodine, the work has not depended upon color reactions but on crystals observed under the microscope. Color reactions are useful to locate a substance

1Tunmann, O. Pflanzenmicrochemie. Berlin. 1913.
2Molisch, H. Microchemie der Pflanzen. Jena. 1913.
3Balch, D. M. Journ. Indust. & Engin. Chem. 1:21-38. 1915.
4Stewart, G. R. Journ. Agr. Research 4:21-38. 1915.
5Turrentine, J. W. U. S. Senate Doc. No. 190:220-221. 1911.

or tissue, but unless the colors depend upon the formation of definitely known compounds, they cannot add much to our knowledge of the micrometabolism of the cell. However, if the reaction is dependent upon the formation of characteristic crystals or precipitates with a definite solubility, the results will be as conclusive as those obtained in gross qualitative analyses.

Calcium.—The sections were placed in 3% sulphuric acid and allowed to evaporate for several hours. Crystals of calcium sulphate were formed (*Figs.* 8, 9, 10). Other methods tried were the precipitation of calcium oxalate with ammonium oxalate, and of calcium carbonate with ammonium carbonate. Neither of these methods produced distinctive crystals; only amorphous precipitates were formed.

Magnesium.—The method given by Richter[6] was found to be very satisfactory. The sections were placed in a drop of .1% $NaHNH_4PO_4$+ $12H_2O$ and placed in a damp ammonium atmosphere. After some time small crystals of magnesium-ammonium phosphate were formed (*Fig.* 6).

Sodium.—The presence of sodium in the cell is demonstrated with great difficulty. A good reaction, different from Molish[2] and Tunmann[1], was obtained when the sections were heated to about 60° C. for a half hour in a 10% solution of uranium acetate, followed by an application of a drop or two of dilute acetic acid. Heating the sections probably caused the solution to enter more rapidly. The sections were then allowed to evaporate to almost complete dryness. Various sized crystals were formed, the smaller ones were colorless and the larger ones light yellow. In plant tissues, magnesium is the only metal that would cause an error in the results. In this case sodium-magnesium-uranyl acetate would be formed, which produces colorless rhomboidal crystals. A few such crystals were formed. However, these also show the presence of sodium (*Figs.* 1, 2).

Potassium.—The most characteristic reaction of potassium is obtained with platinum chloride, but as with sodium it is very difficult to obtain crystals within the cell. The sections were placed in a 10% alcoholic solution of platinum chloride which was then allowed to evaporate. Crystals of potassium-chloroplatinate were formed; some inside the cell, but a greater percentage outside (*Figs.* 4, 5). A quicker and easier method was to use a solution of 30 gr. of cobalt nitrate and 25 gr. of sodium nitrite in 75 cc. of dilute acetic acid. As soon as the reaction within the solution ceased, 25 cc. of water was added and the whole filtered. In the presence of potassium a precipitate of potassium cobalt nitrite is formed (*Fig.* 2). Ammonium compounds, however, react with this solution.

[6]Richter, O. Sitzungsber. d. Kais. Akad. d. Wiss. i. Wien 3:171. 1902.

Chlorine.—The sections were placed in a solution of silver nitrate and the white flocculent precipitate of silver chloride was formed. This was recrystallized by adding several drops of concentrated ammonium hydroxide and allowing to evaporate. Definite crystals of silver chloride were obtained.

Sulphates.—Barium chloride was used to precipitate the sulphates, since it forms an insoluble precipitate with silicates and sulphates only. Silicates are lacking in *Nereocystis* and thus a precipitate would indicate only sulphates. These results were checked by testing the solubility of the precipitate in acids, barium sulphate being insoluble in dilute hydrochloric and nitric acids.

Carbonates.—Sections were mounted on a slide, under a cover glass, in a concentrated solution of hydrochloric acid. Bubbles could easily be seen under the microscope. The carbonates were decomposed by the acids and bubbles of carbon dioxide were given off.

Phosphates.—The sections were placed in a solution of dilute ammonium molybdate and heated for a half hour at $50°$ C. A yellow amorphous precipitate of $(NH_4)_3PO_4.MoO_3$ was formed.

Iodine.—A 10% solution of sodium nitrite was added to sections on a slide, together with a few starch grains. After a few minutes a few drops of a 5% solution of hydrochloric acid were added. Bubbles of hydrogen iodide were immediately formed. If now a cover glass is put over the sections so as to keep the bubbles from escaping, the starch grains next to the bubbles are colored blue. This was found to give better results than the method suggested by Molisch and Tunmann.

TABLE 1. *Summarizing the results obtained in the preceding experiments.*

Fronds—	Ca	Mg	Na	K	Cl	So$_4$	CO$_3$	PO$_4$	I
Total reaction	2	1	3	3	3	2	2	1	2
Reaction in cell	2	1	1	1	3	2	1	1	
Stipe—									
Total reaction	2	1	3	3	3	2	2	1	2
Reaction in cell	2	1	1	1	3	2	1	1	
Holdfast—									
Total reaction	2	1	3	3	3	2	2	1	2
Reaction in cell	2	1	1	1	3	2	1	1	

The figures 1, 2, 3 denote little, medium, and great intensity of the reaction, respectively.

The above data indicate the success of microchemical technique, not the demonstration of additional compounds in the kelp, since these constituents have been found to be present by macrochemical analyses. However, this method has shown that all these constituents occur in solution in the cells of the fronds, stipe and holdfast of the plant.

The permeability of the cell to the reagent undoubtedly is a factor in the success of microchemical analyses. If the protoplast is impermeable to it, no reaction could occur. But if the presence of the solution

changes the permeability so there will be exosmosis, the reaction will not be within the cell. This may explain why few crystals are formed within the cell in the reactions for potassium and sodium. Czapek[7] has stated that ionization is a factor. However it is not certain whether all reactions must be ionic.

If the percentages of the inorganic constituents in the cell are compared with those of sea-water, it is readily seen that the nature of the salts depends upon the selective absorption of the protoplast. The proportions within the cell are quite different from those in solution in the sea-water. The dissolved solids in sea-water are given as ions in the following,: Na, 30.64%; Mg, 3.76%; Ca, 1.20%; K, 1.09%; Cl, 55.21%; SO_4, 7.70%; CO_3, .21%; Br, .19%.[8]

The percentage of sodium in sea-water is about thirty times that of potassium, but the quantity of potassium in the cell far exceeds that of sodium. Again, iodine is present in sea-water in such small quantities that it can hardly be detected, yet it can easily be detected in the cell.

This large percentage of potassium may have some significance. It has been found to be essential in plant growth and metabolism. In metabolism it has been connected with the formation of carbohydrates and proteins.[9] Schimper[10] showed that potassium was essential to the formation of the primordia of organs and that within certain limits the size depended upon the amount present. Although it was not possible to test the amount of potassium present in the actively growing region of the stipe and fronds, it may be a factor in determining the size of the plant.

CELL WALL

In general the composition of the cell walls of the algae is uncertain. In a large number of cases the basic substance seems to be cellulose, but there are other substances present that do not respond to the ordinary cellulose reactions.

In the Cyanophyceae the presence of cellulose is uncertain.[11] According to Gomont[12] and others the walls in general are resistant to acids, copperoxyammonium and iodine. Lemaire,[13] using color reactions, called the gelatinous material in the cell walls of *Nostoc*, *Glococapsa* and similar algae a pectin substance. Virieux[14] found callose in the Cyanophyceae.

In the green algae the cell walls have been found microchemically to be of cellulose, corresponding to the cell walls in the parenchyma tissue of higher plants. The products of hydrolysis, however, differ; for instance,

[7]Czapek, F. Chemical Phenomona in Life, p. 74. New York. 1911.
[8]Murray, J., and Hjort, J. The Depths of the Ocean, p. 176. London. 1912.
[9]Duggar, B. M. Plant Physiology. 172. New York. 1913.
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[11]Czapek, F. Biochemie der Pflanzen; 2nd ed. 1:640. Jena. 1913.
[12]Gomont, Bull. Soc. Bot. 35: 1888.
[13]Lemaire, A. Journ. de Bot. 15:302. 1910.
[14]Virieux, J. Compt. rend. 151:334. 1910.

Müller[15] found glucose and xylose in *Cladophora,* and Röhmann[16] found in *Ulva* a methyl pentosan which gave rhamnose. König and Brettels[17] found the same products in *Enteromorpha* that Röhmann found in *Ulva.*

The Rodophyceae have more or less cellulose in their walls. In some there is another substance present that becomes gelatinous in boiling water.[11] The gelatinous substance obtained from *Chondrus crispus* and *Gigartina mamillosa* has been called carragcen. This "carrageenschleim" is insoluble in copperoxyammonium and according to Tunmann gives a light red color with iodine. Hydrolyzing with nitric acid gives about 20-28% galactose. A reddish color is also given with agar-agar, indicating that they may be similar substances.

The Phaeophyceae seem to be the most thoroughly investigated. It has been shown that the cell wall of *Fucus* is composed of cellulose and a second substance which gave a blue color with iodine in potassium iodide and sulphuric acid. In 1850, Stenhouse[18] treated *Fucus* with sulphuric acid and obtained a slight precipitate which he called fucosol. Later Maquenne[19] established the composition as furfurol and methyl furfurol, the last being formed from methyl pentose. Tollens and Günther[20] showed that the methyl pentose is an isomer of rhamnose and reduces Fehling's solution. This substance, which is called fucose, gives methyl furfurol when treated with hydrochloric acid. It also forms an osazone. Fucosan then is that substance which upon hydrolysis yields fucose.

Stanford[21] isolated a substance from Laminaria which he called algin. Algin is separated by digesting the plant material in the cold for 24 hours with a dilute solution of sodium carbonate or other alkali. The thick sirupy mixture which results is filtered by suction. The filtrate is acidified with hydrochloric acid and a heavy yellow precipitate is formed. Exposure to the air turns the precipitate a dark brown, and when dried it becomes a dark colored hard substance. Hoagland[22] found that the moist precipitate gave a good reduction with Fehling's solution after being boiled with 2% sulphuric acid. He concluded that algin has weakly acid properties and is a very complex resistant compound of the pentosan type because furfurol is produced upon hydrolysis.

The cell well of *Nereocystis* seems to be somewhat similar to that of *Fucus* in that it is made up of a cellulose substance, and a second substance which is algin in *Nereocystis* and fucosol in *Fucus.* Fucosol may be similar to algin since they are both precipitated with acids and yield

15Mueller, K. Ztschr. Physiol. Chem. 45:265. 1905.
16Roehmann. Festschr. f. salkowski. 1904. (Rev. in citation 11, p. 641.)
17Koenig and Brettels. Ztschr. Untersuch. Nahr. Genussmittel 10:157. 1905.
18Stenhouse, J. Lieb. Ann. 74:278. 1850.
19Maquenne. Compt. rend. 109:571, 603. 1889.
20Tollens and Guenther. Ber. Chem. Ges. 23:2585. Lieb. Ann. 271:86.
21Stanford, E. C. C. Chem. News 47:254-257; 47:267-269. 1883. Journ. Chem. Indust. 3:297-303. 1884.
22Hoagland, D. R. Journ. Agr. Research 4:39-58. 1915.

furfurol upon hydrolysis.   As in *Fucus,* algin was found to give a blue
reaction with iodine in potassium iodide and sulphuric acid.

Sections of the different tissues of *Nereocystis* were placed in copper-
oxyammonium.   Potato sections were used as a check, since their cell walls
are known to be cellulose.   These sections were completely dissolved at
the end of 36 hours, but sections of the holdfast, stipe and fronds of *Nereo-
cystis* were not dissolved at the end of that time; consequently they were
allowed to stand 5 days longer.   At the end of this time no further action
had taken place.   This shows that if cellulose was present it did not com-
pose the entire wall, and that at least part of the wall was made up of
a substance that was insoluble in copperoxyammonium.

Some sections were then put in a dilute sodium carbonate solution
and left for about 48 hours; at the end of this time the sections were
very soft and the cells easily broken apart.   These were also left in the
solution for a longer period of time, but at the end of 8 days they still
retained their cellular structure.   These sections were washed with water
and then put into copperoxyammonium.   At the end of 48 hours they
were entirely dissolved.   Since cellulose is dissolved in copperoxyammo-
nium, and algin in sodium carbonate, it seems evident that the cell wall
of *Nereocystis* is made of cellulose and algin.   Whether the algin forms
a loose chemical compound with the cellulose or whether it merely forms
a layer around the wall could not be determined.   Since the cells were
easily broken apart in the sodium carbonate solution, there seems to be
an indication that algin may form a part of the substance which holds the
cells together.

SUMMARY

1.   The inorganic constituents of *Nereocystis luetkeana* can be dem-
onstrated microchemically in the cells of the fronds, stipe and holdfast.

2.   The cell wall seems to be made up of cellulose and algin.

3.   Probably algin is the principal substance that holds the cells
together.
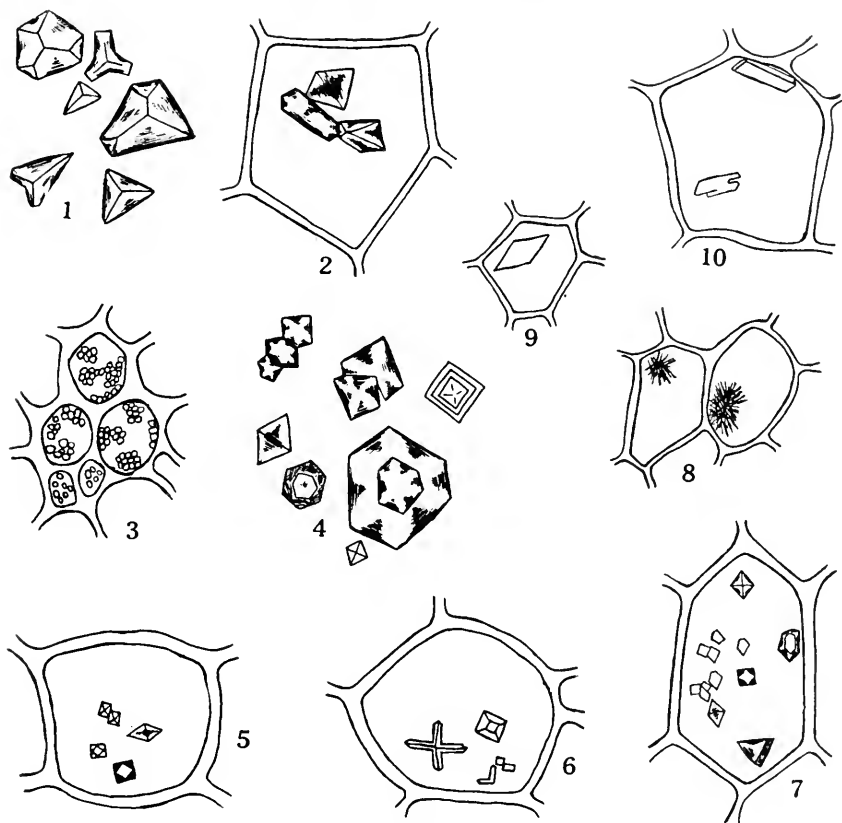
J. Karrer, Del.   PLATE 41

All drawings, $\times 220$.

Fig. 1. Crystals of sodium-uranyl acetate.

Fig. 2. Crystals of sodium-uranyl acetate within the cell.

Fig. 3. Precipitate of potassium-cobalt nitrite in lower stipe.

Fig. 4. Crystals of potassium chloroplatinate.

Fig. 5. Crystals of potassium chloroplatinate within the cell.

Fig. 6. Crystals of magnesium-ammonium phosphate in the stipe.

Fig. 7. Crystals of silver nitrate in the stipe.

Fig. 8. Crystals of calcium sulphate in the fronds.

Fig. 9. Crystals of calcium sulphate in the holdfast.

Fig. 10. Crystals of calcium sulphate in the stipe.

Spirogyra dubia longiarticulata   Kütz. in Washington

Grace A. Hill, University of Washington, Seattle.

Filaments 43-50 μ in diameter; cells 5 diameters long; chloroplasts 2-3, narrow, making 1-3 turns in the cell; fertile cells slightly swollen; spores brownish at maturity, ovoid-ellipsoid, about 40 μ in diameter, 1-2 diameters long. (*Collins.*)

Certain features of the plants examined (*Plate* 42) are better described as follows: Filaments 42-53 μ in diameter; cells 5-10.5 diameters long; chloroplasts 2-4, 9-12 μ wide, making 1-5 turns in the cell; pyrenoids 4-5 per half turn.

Found at Seattle, Washington, Nov., 1916, in roadside ditch, by A. M. Hurd.
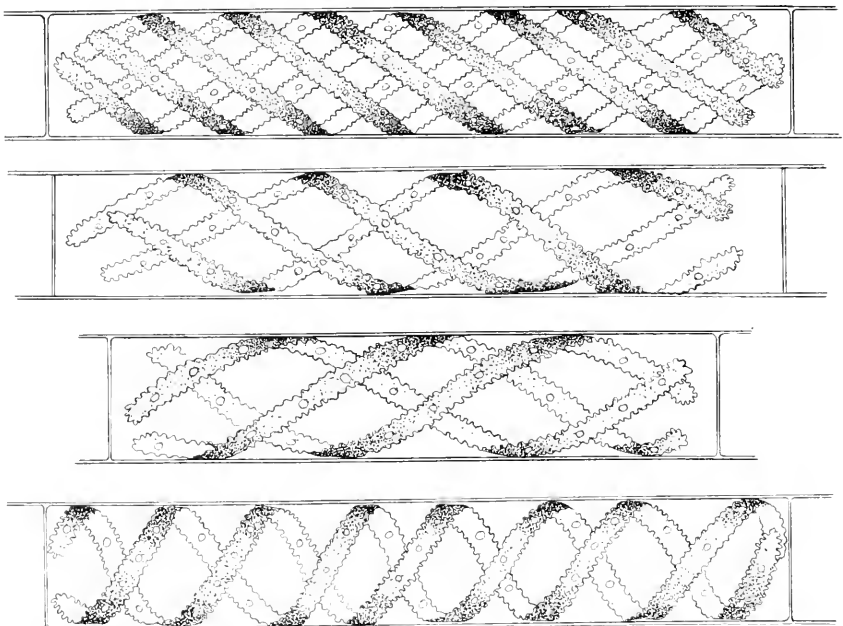
G. A. Hill, Del.   PLATE 42   Drawings, $\times$ 304.

Acidity of Marine Algae

Lois Clark,

University of Washington, Seattle.

During the summer of 1916 experiments were undertaken at the Puget Sound Marine Station to determine whether the juices of marine algae are acid or alkaline, and what relation if any these reactions bear to rapidity of growth and to the part of plant selected. Three green, eight brown and fifteen red algae were experimented with. All of these gave an acid reaction.

The morning, noon and evening tests (table 1) were made either on the same day or early the next morning between 3:00 A. M. and 6:00 A. M. The material was washed very carefully in neutralized sea-water. The surplus water was then shaken out. No attempt was made to dry the plants entirely. The alga was then put through a meat chopper, in which a medium knife was used. At first the juice was pressed out through a cloth; but this proved unsatisfactory, as very little juice could be forced from the pulp. The results given below were obtained from juice expressed by means of a jelly-press. The chopped alga was placed in a cloth, then put into the press, and pressure applied.

There was great difficulty in getting a clear solution. Since titration presupposes a clear solution there is a wider limit of error in the results than there would otherwise be. This is especially true for many of the reds, and for two of the greens. To overcome this a charcoal filter was tried, but with little success. 5-10 cc. of the juice with 4 times as much neutralized sea-water was used in each trial. Titration was made with .02 normal sodium hydrate except in two extreme cases. Phenolphthalein and alizarine paper were used as indicators. The latter was fine filter paper dipped in an alcoholic solution of alizarine. The results are stated in per cents of any normal acid.

From table 1 one is led to conclude that color is not a factor affecting the acidity to any considerable extent; and that depth of water has no particular influence. From table 2 it appears that the stipe and bulb are more acid during the daytime. Why these should be so and the fronds otherwise, is not clear, for the growing regions are the stipe and fronds. From table 3 it is evident that the receptacles are much less acid than the other parts. But they contain more water, and therefore would contain less acid per cc. of sap. The vegetative portions of *Fucus* (table 3)

seem to be decidedly more acid during the afternoon. There is some suggestion of greater acidity in the growing portions of *Nereocystis*, suggesting a possible relation to Schley's (Bot. Gaz. 56: 480-489. 1913) findings in angiosperm seedlings, but the results are not conclusive.

TABLE 1.   *Showing relative acidity at different times of the day.*

	Green Algae 3-6:30 A.M.	10-11:30 AM.	2-4:30 P.M.	Where Collected
Enteromorpha linza	0.326	0.2325	0.1925	Shore
Ulva lactuca	0.413	0.226	0.316	Shore
Cladophora arcta	0.78	0.42	*	Shore
Brown Algae				
Agarum fimbriatum, blade	2.31	2.475	2.35	Shore
Agarum fimbriatum, midrib	0.72	1.34	1.06	Shore
Desmarestia ligulata	0.75	0.58	0.493	Dredged
Desmarestia aculeata	0.73	3.10	0.725	Dredged
Costaria costata	0.253	0.176	0.25	Shore
Fucus evanescens, vegetative ..	0.83	0.88	1.28	Shore
Fucus evanescens, receptacles...	0.16	0.13	0.22	Shore
Leathesia difformis	0.273	0.15	0.13	Shore
Nereocystis luetkeana, holdfasts.	0.371	1.02	0.32	Shore
Nereocystis luetkeana, stipes	0.26	0.735	0.62	Shore
Nereocystis luetkeana, bulbs ..	0.296	0.313	0.29	Shore
Nereocystis luetkeana, fronds..	0.262	0.156	0.10	Shore
Laminaria saccharina	0.286	0.143	0.303	Shore
Red Algae				
Callymenia phyllophora	0.51	0.48	0.57	
*Ceratothamnion pikeanum	0.36	0.36	0.293	Shore
Dasyopsis plumosa	1.03	0.316	0.492	Shore
Fauchea laciniata	0.496	0.76	0.47	Dredged
Gigartina mamillosa	0.296	0.42	0.332	Shore
Gigartina radula	0.326	0.225	0.18	Dredged
Gloiopeltis furcata	0.323	0.383	0.266	Shore
Halosaccion glandiforme	0.58	0.346	0.29	Shore
Iridaea laminarioides	0.423	0.243	0.271	Shore
Nitophyllum latissimum	0.77	0.86	0.23	Dredged
Nitophyllum ruprechtianum	2.36	2.18	2.00	Dredged
*Polysiphonia Sp.	0.45	0.40	0.31	Shore
*Ptilota pectinata	0.58	0.48	0.62	Shore
Rhodymenia pertusa	0.153	0.24	0.25	Dredged
*Rhodomela larix	0.80	0.61	0.45	Shore

*Results only approximately correct since juice was very red in color.

TABLE 2.   *Showing acid determinations for Nereocystis luetkeana about of nearly 3 hours during the 24.*

Time—	Holdfast	Stipe	Bulb	Fronds
4-5 A. M.	0.371	0.26	0.296	0.263
6:45-7:30 A. M.	0.40	0.365	0.365	0.2225
9:30-10:15 A. M.	1.02	0.735	0.313	0.156
12:30-1 P. M.	0.38	0.68	0.346	0.15
4:15-4:45 P. M.	0.32	0.63	0.29	0.10
6:30-7:30 P. M.	0.29	0.613	0.36	0.106
9-10:15 P. M.	0.47	0.366	0.156	0.136
Midnight-2 A. M.	0.40	0.30	0.176	0.116

TABLE 3.   *Showing acid determination for Fucus evanescens at intervals of nearly 3 hours during most of the 24.*

	6 A. M.	9 A. M.	11:30 A. M.	2 P. M.	5 P. M.	8 P. M.	10:30 P. M.
Vegetative	.83	.79	.88	1.28	1.74	1.28	.96
Receptacles	.16	.11	.13	.14	.22	.18	.14

Carbon Monoxide in the Pneumatocyst of Nereocystis*

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The gas content of the floats which buoy up certain marine algae have been subjected to analysis by Rosanoff (7), Wille (11), and Lucas (5), who report an oxygen nitrogen mixture with composition varying from that of air, depending upon the condition.

Zeller and Neikirk (12) in 1914, examined the gas contained in the large Pacific Coast kelp *Nereocystis luetkeana* and reported carbon dioxide as well as nitrogen. Samples collected in the early morning were high in carbon dioxide and low in oxygen and the reverse was true for samples collected at evening. A summary of their results is given in table 1. The author has added the difference column showing the per cent

TABLE 1. *Summary of results by Zeller and Neikirk, with N column added.*

	Average per cent oxygen	Average per cent carbon dioxide	Difference called nitrogen	Number of determinations
Gas collected 3-4 A. M.	10.96	2.503	87.537%	9
Gas collected 3-4 P. M.	12.304	0.293	87.403%	6

of unabsorbed gas which was assumed to be nitrogen and which is practically the same in each case. Among the individual measurements given by Zeller and Neikirk the deviation from the mean values for oxygen and carbon dioxide are slight. Figures for fifteen analyses are given and no statement is made as to how extensively the investigations were carried out. Zeller and Neikirk used a Hempel apparatus consisting of a modified Winkler gas burette, a simple absorption pipette for carbon dioxide, and a double absorption pipette for oxygen. They arrived at the conclusion that "the pneumatocyst of *Nereocystis* is not merely a means by which the plant is buoyed up to the light, but it serves as a reservoir in the gas exchange of the metabolic processes."

At the suggestion of Dr. T. C. Frye, Director of the Puget Sound Marine Station, the author undertook to check these results. More refined methods of analysis were used and numerous measurements were made, extending over the period from June 10th to August 20th, 1916, but the results failed to check the work of Zeller and Neikirk. This is brought

*The subject matter of this article is to appear in the January, 1917, number of the Journal of the American Chemical Society.

out clearly in the quantitative data to be given later, which shows that
carbon dioxide was present only occasionally in quantities large enough
to measure with the apparatus used for technical gas analysis, and that
when it was found, the quantities were minute. The oxygen content was
found to run higher than reported by Zeller and Neikirk (average, about
18%), and the range of variation among individual specimens was so great
that generalizations with reference to daily changes with light scarcely
seem justified.

For the more complete gas analyses the Morehead apparatus was
used, for which the degree of accuracy is 2 to 3 parts per thousand. De-
terminations were made for carbon dioxide, illuminants, (that is, unsat-
urated hydrocarbon gases), oxygen, carbon monoxide, saturated hydrocar-
bon gases (calculated as methane), and hydrogen. The remainder of the
gas not absorbed was assumed to be nitrogen and water vapor, the rare
inert gases of the atmosphere not being considered. This covers pretty
well all of the possible substances which might occur in the kelp gas.
Such gases as hydrogen sulfide, phosphene, ammonia, etc., which certainly
are not to be expected, would be easily detected by odor and by simple
chemical tests even if present in traces.

Within the limit of accuracy of the analytical methods used, neither
hydrogen nor hydrocarbons were found in the kelp gas, although the gas
has an odor which is probably due to minute traces of one or more organic
substances. A more complete investigation of the possible occurrence of
hydrogen or hydrocarbon gases is to be made as soon as suitably delicate
apparatus can be constructed.

Zeller and Neikirk assumed that the gas remaining after the absorp-
tion of carbon dioxide and oxygen was nitrogen. The author was sur-
prised to find in addition carbon monoxide in quantities ranging from one
to twelve per cent, with an average of about 4%. This fact was con-
firmed by the analysis of gas from a little less than one thousand kelp
plants. Since *carbon monoxide has never before been found in the free
state in a living plant,* so far as the writer could find, the following qual-
itative tests were made to demonstrate its presence, and in every case the
reactions were pronounced and positive in their character.

White paper moistened with palladium chloride turned black in the
gas from the kelp but was unchanged in the air. A check with known
carbon monoxide also turned the palladium chloride paper black.

Human blood diluted with 200 times its volume of distilled water
gave a yellowish-red solution which changed to a pink on contact with
the gas.

Vogel's spectroscopic method of analysis for carbon monoxide haemo-
globin, which is the final toxicologic test, gave positive results, as is clearly

shown by the series of photographs given in plate 43. The characteristic absorption spectrum of dilute normal blood, that is, haemoglobin, shows two dark bands in the yellow and green region (see *E, plate* 42). *D* of the same plate shows the absorption spectrum of the same blood after it has been treated with ammonium sulfide and the oxyhaemoglobin reduced; the two dark bands which have disappeared are replaced by a single, less clearly

A   Known CO

B   Known CO$+(NH_4)_2$ S

C   Kelp Gas$+(NH_4)_2$ S

D   Normal Blood$+(NH_4)_2$ S

E   Normal Blood

F   Kelp Gas
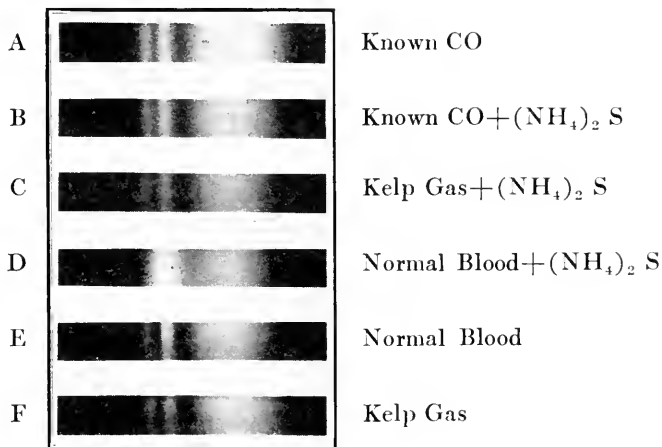
PLATE 43

marked, band. As shown in *A*, the absorption spectrum of blood which has been treated with known carbon monoxide is almost identical with that of normal oxyhaemoglobin (*E*), but on treatment with ammonium sulfide the carbon monoxide haemoglobin is not reduced and there is no change in the absorption spectrum (*see B*). Samples of the dilute blood treated with kelp gas gave the absorption spectrum shown in *F* and which is similar to *A* and *B* and was not changed (compare *C*) by attempted reduction with ammonium sulfide. Hempel (Methods of Gas Analysis: Dennis' translation of 3rd edition, page 211) says: "This reaction is of especial significance, because the carbon monoxide cannot be confounded with another gas."

A guinea pig placed in a vessel through which kelp gas was passing died in less than ten minutes. Death was not due to the absence of oxygen, for the gas contained about 18 per cent of oxygen, and fresh gas was being continuously forced through the vessel. Postmortem examination of the body showed the characteristic appearances associated with carbon monoxide poisoning. The nose, lips, and conjunctivae had assumed a red color. The blood was of a bright scarlet color which seemed permanent, for it was still unchanged after three weeks' exposure in an open evapor-

ating dish. The diluted blood subjected to spectroscopic examination showed the two dark absorption bands, which were not changed on warming the blood with ammonium sulfide. Ferrous sulfate did not cause the blood to darken, as is the case with normal blood. Two cubic centimeters of the "carbon monoxide" blood from the guinea pig was mixed with an equal quantity of water and three drops of a one-third saturated solution of copper sulfate gave a brick-red precipitate, while normal blood gives a greenish-brown precipitate.

A canary bird lived less than fifteen seconds in gas from the kelp bulb. Removal of the feathers from the breast showed that the skin was a mottled red. The internal organs were a bright red and the blood a cherry red.

A young chicken died in the kelp gas in about 1 minute. Another chick of the same size and age was killed in the same time by a mixture

Mercury trough.

Cut end of stipe
closed by adapter.

Adapter
conected to
three way stop-cock.

First sample of gas
drawn into pump. ⟶

⟶ Analytical
apparatus.
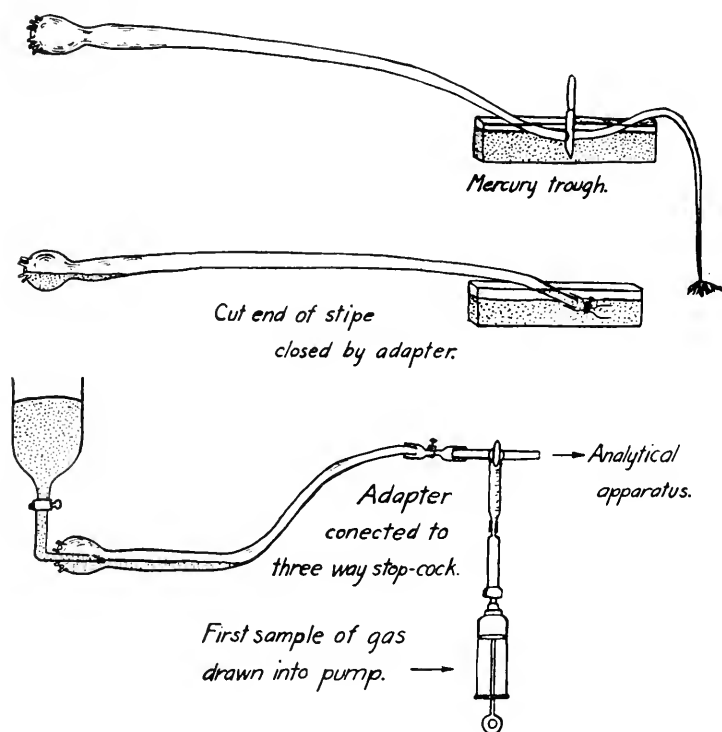
PLATE 44

of 1 part illuminating gas (CO, 15%) with 5 parts of air. The blood, subjected to spectroscopic examination and compared with blood from a similar chick killed by decapitation, showed results analogous to those pre-

viously discussed. The blood from the chick killed by the kelp gas was not reduced by ammonium sulfide.

The above qualitative tests were quite conclusive and are preliminary to the discussion of quantitative results, which follow.

In the early part of the work extra precautions were taken to prevent loss of carbon dioxide. The method of collecting the gas for examination is illustrated by Fig. 2, the gas being forced out of the cavity and into the analytical apparatus by mercury. Thus the gas came in contract only with mercury while being transferred to the absorption apparatus.

Since the "complete" analysis of the gas, previously discussed, did not show hydrogen or hydrocarbons, the analytical device used for most of the work was a Williams modified Orsat appartus, specially designed for the determination of carbon dioxide, oxygen, and carbon monoxide. Results which checked to within two to three parts per thousand were obtained. Throughout the work fresh carefully prepared reagents were used, and the accuracy was tested daily by the analysis of known gases and air. In all cases a 100 cc. sample of gas was analyzed.

Table 2 gives the results of 12 analyses which are typical of those

TABLE 2.   *Results of typical gas analyses, showing small carbon dioxide content; gas collected over mercury.*

					SAMPLES						
%CO 3.8	3.0	3.4	1.1	2.6	5.6	5.0	2.6	4.2	3.2	6.5	4.3
%O^2 .... 18.8	21.2	19.5	20.0	16.8	24.7	18.0	17.4	23.0	23.4	18.6	18.3
%CO^2 .... 0.0	0.0	0.3	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 3.   *Comparison of gas analyses at various times of day and night.**

Hour collected	Pressure in mm.	% CO_2	% O_2	% CO	Hour collected	Pressure in mm.	% CO_2	% O_2	% CO
Midnight ...	585	0.0	21.2	3.4	11 A. M. ...	575	0.0	17.3	3.7
Midnight ...	555	0.0	20.8	5.2	11 A. M. ...	595	0.0	20.3	2.0
Midnight ...	555	0.5	22.2	7.0	11 A. M. ...	540	0.0	17.3	3.7
Midnight ...	555	0.0	20.1	3.4	11 A. M. ...	565	0.0	20.0	10.3
Midnight ...	530	0.0	18.9	1.9					
4 A. M. ...	625	0.0	18.0	1.3					
4 A. M. ...	570	0.0	17.8	3.2					
4 A. M. ...	520	0.0	19.8	7.0	5 P. M. ...	670	0.0	22.1	2.6
4 A. M. ...	530	0.0	22.4	5.0	5 P. M. ...	625	0.0	17.8	2.0
4 A. M. ...	585	0.0	21.2	5.2	5 P. M. ...	590	0.0	14.4	3.2
4 A. M. ...	535	0.0	17.4	12.2	5 P. M. ...	635	0.0	20.2	7.2
8 A. M. ...	595	0.0	22.9	7.5	9:30 P. M.		0.0	17.5	1.5
8 A. M. ...	580	0.0	19.9	1.2	9:30 P. M.		0.0	16.0	5.4
8 A. M. ...	555	0.0	19.6	1.7	9:30 P. M.		0.0	15.2	1.5
8 A. M. ...	530	0.0	16.4	4.8	9:30 P. M.		0.0	16.0	0.4
8 A. M. ...	565	0.0	20.0	7.0	9:30 P. M.		0.0	19.5	2.2
8 A. M. ...	585	0.0	16.9	8.6					

*The data were taken from samples collected July 4, 1916. The day was bright except for an hour in the early afternoon. The tide was high (+8.7 ft.) between 5 and 6 A. M., then low (+2.3 ft.) at noon and high (+11.2 ft.) again between 8 and 9 P. M. Temperature of the water 10° C.

obtained when special precautions were taken to prevent loss of carbon dioxide. These figures make it clear that carbon dioxide is present only very occasionally and then in small, though unmistakable, quantities.

Similar results were obtained by a more extended series of analyses in which the gas was displaced by water saturated with gas from other specimens which had been collected at the same place and time. Mention should be made of one exceptional case in which an apparently healthy kelp showed 1.2 per cent of carbon dioxide.

That the carbon dioxide content did not vary with the time of day is brought out in table 3. The occurrence of carbon dioxide, while seemingly irregular, is of interest and will be investigated by more refined methods than those of technical gas analysis. The presence of carbon

Fronds

←Stipe

A   B

(A) Showing method of collecting gas over sea water
(B) Nereocystis showing fronds

Hold fast

Rock
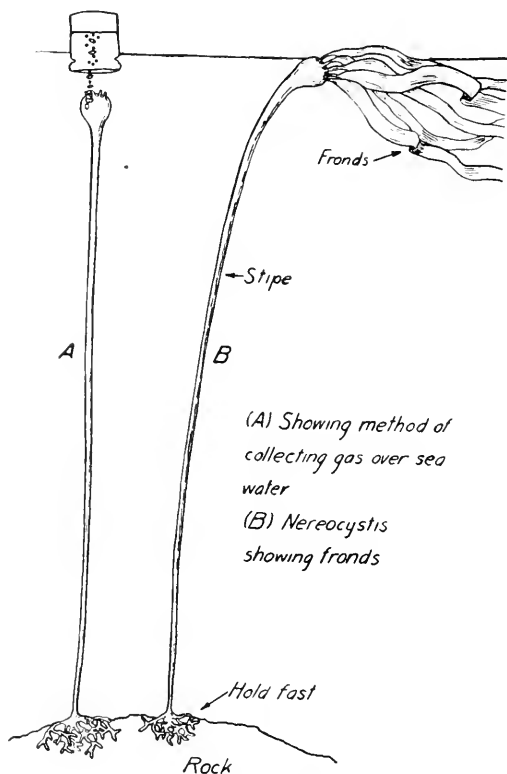
PLATE 45

monoxide is of much more striking interest due to its possible bearing on the mechanism of photosynthesis. Table 3 gives a rather extended set of measurements all made within 24 hours. The gas was collected (*Plate 45*) over sea water in glass jars which were sealed and then brought to the

laboratory for analysis. The samples were in all cases collected from large specimens of kelp from the same location and as nearly uniform in appearance and size as possible. Column 2, table 3, gives the pressures of the gases taken just before collection. The figures show such irregularity that there is no evident relation between pressure and chemical composition of the gas. Also for samples collected at the same hour of the day there is great variation in the percentage composition. For example, in the six samples collected at 8 A. M. the range of carbon monoxide content was from 1.2 to 8.6 per cent, and the oxygen range from 16.4 to 22.9 per cent. The existence of such great variation between individuals would necessitate the analysis of an enormous number of samples in order to obtain average values, which would indicate whether the composition of the gas varies with the time of day, that is, with the light intensity. The rate of flow of water past the plant may have some bearing on the composition of the gas, and it appears to be true that the highest carbon monoxide content is to be found in those larger and more healthy kelps which grow where the tidal currents are the swiftest. The mature kelps have a higher carbon monoxide content than do the young ones.

It has not been determined whether or not the carbon monoxide gas functions actively in the metabolic processes of the plant, whether it is an accumulated waste product or is formed by processes of decay. Work is now under way which it is hoped will answer these questions. No hypothesis is offered by the author, as yet, to account for its presence in the pneumatocyst of *Nereocystis,* but the purpose of this paper is simply to give what has heretofore been lacking, namely, experimental evidence of the actual existence of free carbon monoxide in a living plant.

For those not familiar with the plant in which CO was found, the following brief description is given:

The kelp *Nereocystis luetkeana* is a brown alga thriving only on the Pacific Coast. Its general external appearance is indicated in *B* of plate 45. The stipe is hollow from the bulb-like top to within a short distance of the holdfast. The walls of the stipe are from a quarter to three-quarters of an inch in thickness and are lined with a delicate web-like structure which is relatively quite dry. The hollow space, in large specimens, has a capacity of from three to four liters. The gas is almost always under less than atmospheric pressure. Frye (3) reports an average of 77 mm. of mercury below normal air pressure. The full-grown kelps vary greatly in length. The author has worked with specimens as long as 85 feet, but much longer ones have been reported. Most of this enormous growth takes place in the short period of 10-15 weeks. The largest and healthiest kelps grow where the current flows the strongest and where there is consequently the most chance for the great surfaces of the fronds to

come in contact with fresh sea water. *Nereocystis* selectively absorbs
potassium chloride and it is perhaps significant that while the plant is
about 92 per cent water, more than one-fourth of the remaining 8 per cent
is KCl (6).

These facts, coupled with the unprecedented presence of carbon
monoxide, make this plant of especial interest from a chemical point of
view. Also as a subject for photo-chemical research marine algae offer
an exceptional field, since by reason of their environment they are sub-
ject to relatively constant conditions.

The following is a very brief mention of some of the more general
theories of the photosynthetic steps by which plants build up complex
carbohydrates from carbon dioxide and water:

The Formaldehyde Theory, which was first suggested by Baeyer (1) in
1870, has had the strongest influence in directing investigation dealing with
the mechanism of photosynthesis. Baeyer's theory is, essentially, that
under the influence of sunlight carbon dioxide is decomposed into carbon
monoxide and oxygen. The latter escapes and the carbon monoxide, held
by the chlorophyll, is reduced to formaldehyde, which condenses to sugars.
The steps are indicated by the following equations:

$$CO_2 \rightarrow CO + O$$
$$2H + CO \rightarrow HCHO$$
$$HCHO \rightarrow \text{sugars}$$
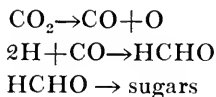
With reference to the last step Baeyer considers that in aqueous solution
formaldehyde is hydrated to form $CH_2(OH)_2$ and that this condenses with
the elimination of water.

Berthelot (2) in 1864 was the first to propose the dissociation of car-
bon dioxide into carbon monoxide and the subsequent reduction of car-
bon monoxide as the initial step in photosynthesis. In 1906 Loeb (4) was
able to break up carbon dioxide into carbon monoxide and oxygen by means
of the silent electric discharge. By using something to absorb oxygen, as
chlorophyll solutions, he obtained both formaldehyde and formic acid, and
on the basis of this work formulated the theory which is summarized by
these equations:

$$CO_2 \rightarrow CO + O_2$$
$$CO + H_2O \rightarrow HCOOH$$
$$CO + H_2O \rightarrow CO_2 + H_2$$
$$H_2 + CO \rightarrow HCHO$$
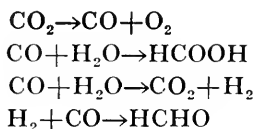
The work of Stoklasa (9, 10) is considered by some to establish the
formaldehyde theory on a firm basis. Stoklasa and his co-workers found that
formaldehyde was formed from carbon dioxide and water under the in-
fluence of ultra-violet light only in the presence of potassium hydroxide

and nascent hydrogen. In his experiments the nascent hydrogen was formed by the action of the potassium hydroxide on a metallic alloy. The potassium hydrogen carbonate, formed by the interaction of the potassium hydroxide and carbon dioxide, is reduced by the light to formic acid, which, in turn, gives formaldehyde, with the subsequent condensation to sugars. An outline of the steps suggested is shown by the equations:

$$CO_2 + H_2O \rightarrow H_2CO_3$$
$$H_2CO_3 + KOH \rightarrow KHCO_3 + H_2O$$
$$2KHCO_3 + light \rightarrow K_2CO_3 + HCOOH + O$$
$$HCOOH + light \rightarrow HCHO + O$$
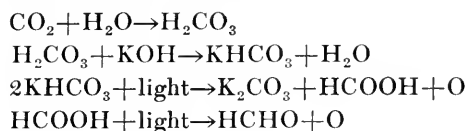
The required presence of potassium hydroxide in Stoklasa's experiments is of interest in view of the fact, previously mentioned, that *Nereocystis* and some other marine plants selectively absorb large quantities of potassium salts from the sea water.

Spoehr (8) shows that carbon dioxide can be reduced to formic acid by light and that under conditions such as exist in the plant leaf, formic acid will form sugar-like substances. He is not ready to announce a "formic acid hypothesis'" but considers that the process of photosynthesis is one of extreme complexity, the chemistry of which is as involved as that of fermentation and enzyme action.

The above review, while fragmentary and incomplete, shows that the theories of photosynthesis have been largely concerned with carbon monoxide and its reduction product, formaldehyde; and with formic acid, of which carbon monoxide may be considered the anhydride. It therefore seems of interest to raise the question as to whether this occurrence of free carbon monoxide in a living plant is unique in nature or more general than has before been suspected.

The author has examined gas from the vesicles of *Egregia menziesii*, and *Fucus evanescens* but found no carbon monoxide. The Supply Department of the Scripps Institute collected gas from *Pelagophycus porra* and *Macrocystis pyrifera* for the author, who found that the former gave evidence of containing a small quantity of carbon monoxide. However, this has not as yet been confirmed and will be more fully investigated next season. In addition, the work is being carried on, to determine if carbon monoxide is present in the air chambers of various land plants.

SUMMARY

(1). The gas in the float of *Nereocystis* contains carbon monoxide, the quantity varying considerably in different individuals.

(2). The presence of carbon dioxide is only occasional and the quantity minute.

(3). Previous work which tended to show that the quantity of carbon dioxide and oxygen varies with the time of day has not been confirmed.

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Origin of Second Spiral in Spirogyra lutetiana

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Filaments 30-36 μ in diameter; cells 3-7 diameters long; chloroplast 1, broad, dentate, dark green, making 3-7 turns in the cell; fertile cells sometimes swollen, sometimes cylindrical; spores polymorphous, either globular, ellipsoid, oblong, cylindric-ellipsoid, pyriform or reniform, yellowish at maturity, 2-4 diameters long, 30-40 μ in diameter. (*Collins.*)

The plants examined were collected in the basin of an old fountain on the campus of the University of Washington in December, 1916. The filaments were only 20-32 μ in diameter. The chloroplasts were 12-15 μ wide, and deviated from the transverse by an angle of 10°-30°, usually about 20° in normal cells. The plants differed from the description above in that the cells were 3-12 times as long as wide; the chloroplasts made 3-8.5 turns per cell; and rather frequently there were 2 chloroplasts per cell (*Figs.* 8, 10, 12). The greater number of turns might be expected from the longer cells.

A study of the origin of the second spiral showed that sometimes there was only 1 when there appeared to be 2, because it doubled back the whole length of the cell (*Fig.* 6). In a few instances, through doubling, there appeared to be 3 spirals (*Fig.* 5); but in such cases the cell was unusually short. It may be that doubling back is due to the chloroplast growing too rapidly for the cell. Various stages of it were observed (*Figs.* 2, 3, 4, 6). Apparently the cell as a rule eventually breaks where it doubles. It appears that breaking at the return bend may occur at any period (*Fig.* 9). Thus one source of the rather frequent occurrence of 2 spirals is explained; by division such a cell obviously forms more cells with 2 spirals.

The cells of *S. lutetiana* seem to be more or less subject to irregularities. Not infrequently a small piece was found broken from the main chloroplast (*Fig.* 7). More commonly the spirals were broken near the middle (*Fig.* 11), whereupon the 2 broken ends passed each other (*Fig.* 12). Thus 2 spirals were formed.

If a cell like that in figure 6 were to divide before the chloroplast breaks at the bend, there would probably be 2 chloroplasts in one of the

cells; but no such case was seen.   These observations may also account for
the variation in the number of chloroplasts in other species of *Spirogyra*.
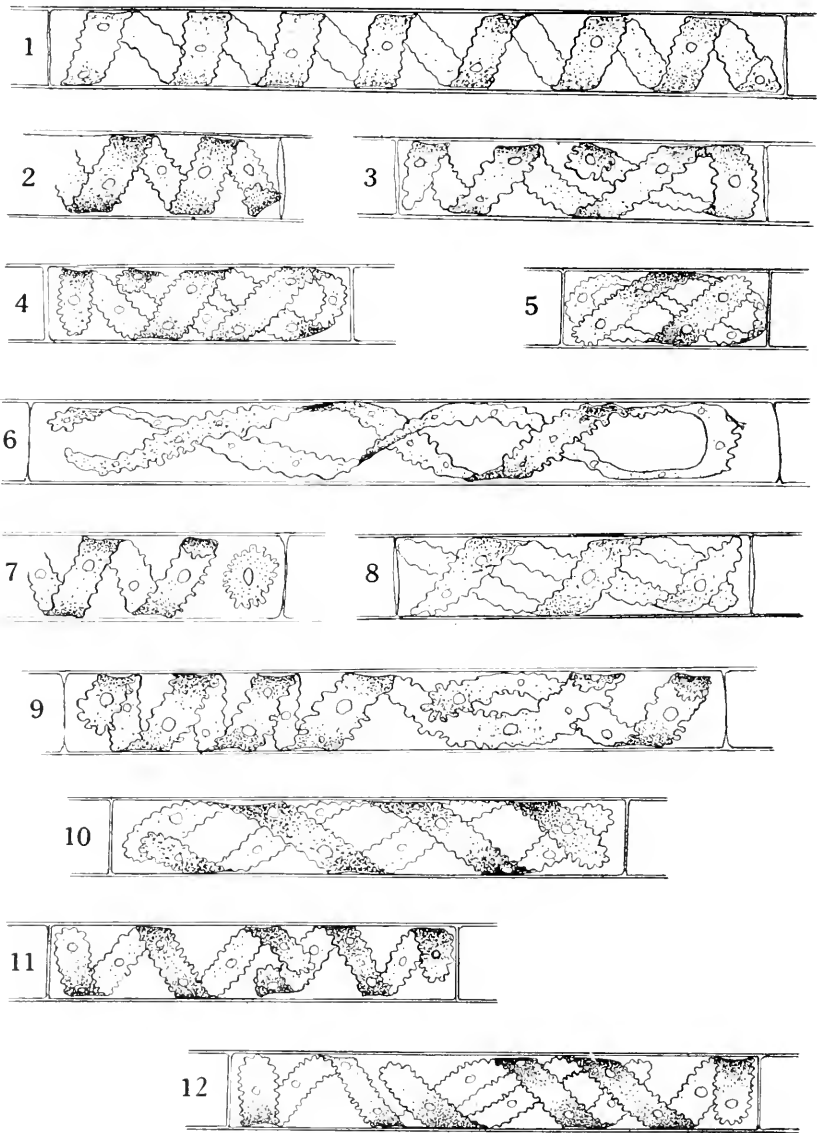
A Key to the Phaeophyceae of Puget Sound

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Phaeophyceae, or brown algae, are well represented on the shores of Puget Sound. In this paper is given an analytical key to the genera and species found in Puget Sound, Washington, using the term "Puget Sound" to include all the bodies of water inside of Cape Flattery on the west and Point Roberts on the north. Short descriptions and illustrations are given for each species.

The keys and descriptions are based primarily upon such distinctions as may readily be observed in the field. Where this is not possible microscopic characters are used for separating genera and species. It must be borne in mind that the key to the genera is intended to hold only for the genera as they are represented by the species of this region and may not hold if the species of other waters are included. Nearly all the determinations were made from living material. The descriptions are not original but in most cases have been checked up with living specimens. The illustrations are sketches from material at hand unless otherwise indicated.

This paper is not claimed to be complete in any sense. It includes all the species of Phaeophyceae at present known to occur within the region but undoubtedly many others will be found in the future. The fact that there is no work in which the student of algae may find a key to or descriptions of even any considerable number of the Phaeophyceae of this region, is at least one justification for offering to my colleagues this very incomplete work, with a hope that it will not only be of some use to them, but that it may result in a more complete knowledge of the marine algae of Puget Sound and vicinity.

Most of the sketches were drawn by Miss Helen C. Gilman of the University of Washington.

The 49 species of Phaeophyceae distributed in 36 genera in Puget Sound fall under the following groups according to Engler's (2) classification. The characterization of groups is somewhat modified.

I. PHAEOSPORALES. Reproductive organs developing from superficial cells.

    1. Ectocarpaceae. All reproductive cells motile and produced in unilocular or plurilocular sporangia. Thallus variable, but without distinct root-like or blade-like parts.

Castagnea	Leathesia	Pylaiella
Chordaria	Mesogloia	Ralfsia
Coilodesme	Myelophycus	Scytosiphon
Colpomenia	Myrionema	Soranthera
Desmarestia	Phycocelis	Sphacelaria
Dictyosiphon	Phyllitis	Striaria
Ectocarpus	Punctaria	

    2. Laminariaceae. Unilocular sporangia present, in large sori; antheridia and oogonia on protonema-like structure, known only in a few species. Plant body variable, differentiated into root-like, stem-like and leaf-like parts (holdfast, stipe and blade), growth intercalary, later with localized intercalary growing region.

Agarum	Egregia	Nereocystis
Alaria	Hedophyllum	Pleurophycus
Costaria	Laminaria	Postelsia
Cymathere	Macrocystis	Pterygophora

II. CYCLOSPORALES. Reproductive organs, antheridia and oogonia, produced in sunken conceptacles. No asexual reproduction by motile spores.

    3. Fucaceae. Antheridia many, with many obovate laterally biciliate sperms. Oogonia large, with two, four or more commonly eight eggs. Plant body parenchymatous, variable in form, often much branched and with many air bladders.

Cystophyllum	Pelvetia
Fucus	Pelvetiopsis

III. DICTYOTALES. Asexual reproduction by non-motile spores. Oogonia with one egg. Antheridia producing one uniciliate sperm in each cell. Sexual and asexual generations alternating regularly.

    4. Dictyotaceae. Plant body flat, membranaceous, with apical growth.

        Dilophus.

ARTIFICIAL KEY TO GENERA

A. Plants filamentous, thread-like, usually much branched.
  B. Plants small, microscopic to about 4 dm. long; sporangia usually present.
    C. Filaments composed of 1 row of cells.
      D. Basal part of the plant consisting of branched filaments; erect filaments usually much branched.
        E. plurilocular sporangia between the cells of the vegetative filaments.   1. *Pylaiella* (p. 254)
        EE. Plurilocular sporangia at the ends of filaments.
                2. *Ectocarpus* (p. 255)
      DD. Basal part of the plant consisting of a cellular disc or pad-like mass; erect filaments usually little or not branched; sporangia at the ends of the filaments.   3. *Phycocelis* (p. 256)
    CC. Filaments composed of several rows of cells; filaments forming a dense tuft; sporangia on short lateral branches.
                4. *Sphacelaria* (p. 257)
    CCC. Filaments composed of many rows of cells forming a more or less hollow much branched filament.
      F. Filaments hollow; sporangia in groups that form transverse lines.
                5. *Striaria* (p. 257)
      FF. Filaments solid above, hollow below; sporangia scattered or if in groups not in transverse lines.   6. *Dictyosiphon* (p. 258)
  BB. Plants large, 4 to 10 dm. or more long, with solid central axis, much branched, forming dense tufts; sporangia seldom present.
                7. *Desmarestia* (p. 258)
AA. Plants not filamentous, not thread-like, branched or unbranched.
  G. Plant not branched.
    H. Plant composed of a large blade with or without distinct stipe.
      I. Plant with a distinct blade, holdfast, and stipe; usually about 1 meter or more long.
        J. Blades with one or more longitudinal ribs.
          K. Blade with one rib.
            L. Blade broad, crinkled, often perforated; rib broad; stipe short.   8. *Agarum* (p. 259)
            LL. Blade broad, not crinkled, not perforated; rib broad; stipe long.   9. *Pleurophycus* (p. 262)
            LLL. Blade narrow, not crinkled, not perforated; rib narrow; stipe usually long.
              32. *Alaria*, without sporophylls (p. 277)
          KK. Blade with 3 to 5 ribs.   10. *Costaria* (p. 262)
        JJ. Blades without longitudinal ribs.
          M. Blade smooth or with 2 rows of cross folds.
            N. Stipe erect; base of blade without hapteres; blade often with 2 rows of cross-folds.   11. *Laminaria* (p. 262)

NN. Stipe creeping, rhizome-like; in older forms stipe ab-
sent and base of blade with hapteres; blade without 2
rows of cross folds, mucilaginous.

12. *Hedophyllum* (p. 266)

MM. Blade with 3 to 5 longitudinal folds.

13. *Cymathere* (p. 267)

II. Plant composed of a regular or irregular thin blade; without dis-
tinct stipe; usually not over 3 or 4 dm. long; holdfast pad-like.

O. Blade narrow, regular, smooth, sporangia over entire surface.

14. *Phyllitis* (p. 267)

OO. Blade broad, irregular, sporangia in scattered spots.

15. *Punctaria* (p. 268)

HH. Plant body composed of a sac, a tube, or an irregular mass.

P. Plants sac-like, mostly epiphytes on other algae.

Q. Sac covered with small spots over entire surface, oval, usually
expanded and filled with water.   16. *Soranthera* (p. 269)

QQ. Sac not covered with small spots, smooth or wrinkled.

R. Sac long, 2 or more times as long as wide.

17. *Coilodesme* (p. 269)

RR. Sac globose or irregular, about as long as wide.

S. Plant body composed of 2 distinct layers, the inner layer
of large rounded cells, the outer layer of more or less
cubical cells.   18. *Colpomenia* (p. 271)

SS. Plant body not composed of 2 distinct layers of cells,
the central part of the plant body composed of re-
peatedly-branching dichotomous filaments which termi-
nate in the outer cells.   19. *Leathesia* (p. 271)

PP. Plant body composed of a single tube.

T. Tubes constricted, not twisted.   20. *Scytosiphon* (p. 271)

TT. Tubes not constricted, twisted.   21. *Myelophycus* (p. 271)

PPP. Plants forming small crusts or spots on rocks or other algae;
composed of microscopic filaments.

U. Plants forming small spots on other algae.

22. *Myrionema* (p. 272)

UU. Plants forming small leathery brown patches or crusts on
rocks   23. *Ralfsia* (p. 273)

GG. Plants branched.

V. Plants with one or more air bladders or swollen tips.

W. Plants large, 3-20 meters or more when mature.

X. Plant with one large air bladder on the end of a long tapering
terete stipe; blades all branching from bladder.

24. *Nereocystis* (p. 273)

XX. Plant with many small air bladders between the blades on
each side of the several strap-like branches of the stipe and
blade.   25. *Egregia* (p. 274)

XXX. Plant with many small air bladders, 1 on the base of most
of the blades; stipe terete, branched.

26. *Macrocystis* (p. 274)

WW. Plants small, 5 cm. to 2 meters when mature.
> Y. Branches dichotomous, usually flattened, with swollen tips.
> > Z. Branches with midrib; oogonia with 8 eggs.
> > > 27. *Fucus* (p. 274)
> > ZZ. Branches without midrib; oogonia with 2 eggs.
> > > a. Eggs of equal size.   28. *Pelvetia* (p. 276)
> > > aa. Eggs of unequal size.   29. *Pelvetiopsis* (p. 276)
> YY. Branches not dichotomous, only the lower branches flattened; upper branches terete, with many small air bladders.
> > 30. *Cystophyllum* (p. 276)

VV. Plants without air bladders or swollen tips.
> b. Branches large, flat, blade-like.
> > c. Stipe prominent.
> > > d. Plant with several to many nearly equal blades on the end of the stipe.
> > > > e. Stipe thin, solid terete or flattened.
> > > > > 11. *Laminaria*, split forms (p. 262)
> > > > ee. Stipe thick, hollow, terete.   31. *Postelsia* (p. 277)
> > > dd. Plant with a terminal blade and several lateral blades near the end of the solid stipe.
> > > > f. Terminal blade with a midrib; stipe plastic, thin, about 1 cm. in diameter.   32. *Alaria* (p. 277)
> > > > ff. Terminal blade without a midrib; stipe erect, "woody," thick, about 2 to 5 cm. in diameter.
> > > > > 33. *Pterygophora* (p. 280)
> > cc. Stipe very indistinct, short.
> > > g. Stipe widening into a ribbed blade from which large blades arise oppositely; blades with delicate ribs and serrate edges, sometimes branching again.
> > > > 7. *Desmarestia ligulata* (p. 258)
> > > gg. Stipe short; branches dichotomous, flat, spreading fan-like.
> > > > 34. *Dilophus* (p. 281)
> bb. Branches small, terete, coming from a more or less solid axis.
> > h. Plant with one distinct central axis with many lateral branches that seldom branch again.
> > > i. Plant composed of closely compacted cells, center solid or hollow, peripheral layer tough; growth apical.
> > > > 35. *Chordaria* (p. 282)
> > > ii. Plant soft, composed of loosely interwoven filaments, growth intercalary.   36. *Castagnea* (p. 282)
> > hh. Plant without a distinct central axis; branches of different lengths, repeatedly branched.   37. *Mesogloia* (p. 282)

1. PYLAIELLA   Bory

1. PYLAIELLA LITTORALIS (L.) Kjellman, Bidr. Skand. Ectocarp. p. 99; (*Ectocarpus littoralis* Ag. Sp. p. 40).   FIG. 1

Plants composed of loosely intertwined light brown or olive green filaments 3 to 15 cm. long; branches few or many, opposite or alternate, narrow, several times as long as wide, not tapering, usually standing at right angles to the main filaments. Chromatophores disc-shaped or sometimes irregular plates, several in each cell. Plurilocular sporangia intercalary with the vegetative cells, in series or single; unilocular sporangia usually in series, on the branches with several vegetative cells on the tip.

A variable species, represented by two varieties, var. *opposita* with opposite branches, and var. *firma* with alternate branches.

Forming dense brown tufts on piles and rocks near low tide mark.

a 1 b	2	3
Pylaiella	Ectocarpus	Ectocarpus
littoralis	siliculosis	confervoides
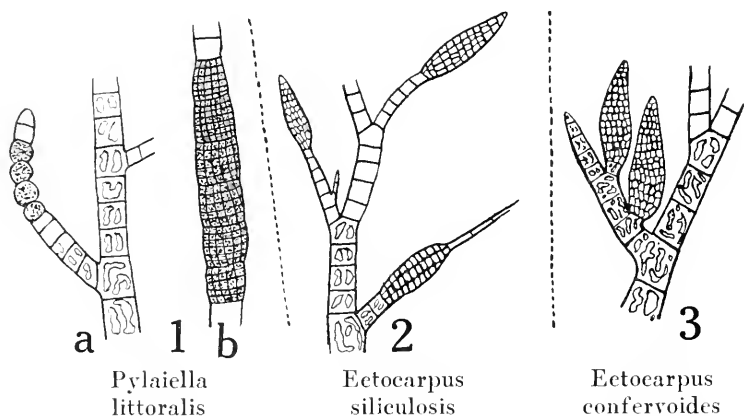
PLATE 47

Fig. 1.   a, Portion of a filament with unilocular sporangia; b, plurilocular sporangium. × about 100.

Figs. 2 and 3.   Portions of filaments with plurilocular sporangia. × about 200.

2. ECTOCARPUS   Lyngbye

Plants filamentous, monosiphonous or sometimes partly polysiphonous, branched or rarely unbranched; attached to substratum or host by creeping or penetrating branching filaments. Tips of branches ending in colorless hairs or all cells of branches containing color; sporangia external, sessile or stalked, terminal or lateral, not intercalary; plurilocular sporangia usually ovate or cylindrical, formed by closely aggregated cells; unilocular sporangia usually oval or globose.

A. Plurilocular sporangia long, with pointed tips; chromatophores irregular or band-shaped or branched.

   B. Sporangia usually on short stalks or sessile, not tipped with hairs.
                                         1. *E. confervoides*

   BB. Sporangia usually on long stalks, not sessile, often tipped with hairs.   2. *E. siliculosus*

AA. Plurilocular sporangia ovate or cylindrical, without pointed tips; chromatophores disc- or lens-shaped.

   C. Sporangia cylindrical, on short stalks.   3. *E. cylindricus*

   CC. Sporangia broadly ovate, truncate, sessile.   4. *E. granulosus*

1. ECTOCARPUS CONFERVOIDES (Roth) Le Jol. List. Alg. Cherb. p. 75; (Roth, Catal. Bot. 1: p. 151-152).   FIG. 3

Plants tufted, two cm. to four dm. long; attached to the substratum by horizontal creeping filaments, often entangled at the base. Branches alternate, gradually tapering, sometimes corticated; larger branches with cells 35 to 50 μ broad, as long to one-half as long as broad; chromatophores large, irregular, band-form, few in each cell. Plurilocular sporangia narrowly lanceolate, subulate to ovate and acute, sessile or short stalked; unilocular sporangia ovate, globose or elliptical.

A variable species represented by at least several forms. On *Nereocystis Luetkeana*, *Desmarestia ligulata* and *Desmarestia aculeata*.

2. ECTOCARPUS SILICULOSUS (Dillw.) Lyngb. Hydrophyt. Dan. p. 131.
                                                 FIG. 2

Plants in tufts up to several dm. long, pale olive-green, soft. Filaments slender, much branched; cells 20 to 40 μ broad, several times as long; chromatophores irregular bands, one or several in a cell; plurilocular sporangia long and narrow, pointed, often ending in a colorless hair, on long many-celled stalks; unilocular sporangia ovate, on lateral branches.

A variable species represented by several forms. Forming light brown mats on rocks in shady places near low tide land.

3. ECTOCARPUS CYLINDRICUS Saund. Phyc. Mem., Calif. Acad. Sci. Bot. 1: p. 150, pl. 16.   FIG. 4

Plants forming a compact mass several mm. long on other algae. Creeping filaments branched; erect filaments simple or with few branches below, of same size thruout; cells 18 to 30 μ wide, usually several times as long as wide; chromatophores numerous, disc-shaped. Plurilocular sporangia lateral, on a one- to several-celled stalk, erect, cylindrical or obovate; unilocular sporangia on different filaments, oval or elliptical, usually on a one-celled stalk or sessile.

Reported from Whidby Island by Setchell and Gardner (14).

4. ECTOCARPUS GRANULOSUS (Engl. Bot.) Ag. Sp. p. 45; (*Ectocarpus se-cundatus* Suhr. Flora 1840, p. 279.   FIG. 5

Plants composed of filaments 1 to 5 cm. long; main branches mostly opposite, many of them corticated; secondary branches opposite, short, given off at wide angles, curved at tips; cells 40 to 75 μ broad, width half to once the length. Plurilocular sporangia abundant, sessile on the secondary branches, broadly ovate, obliquely truncate at the base; unilocular sporangia wanting.

On *Desmarestia ligulata.*
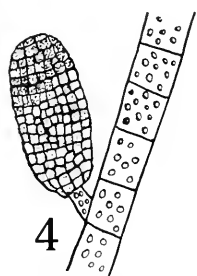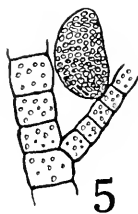
| Ectocarpus cylindricus | Ectocarpus granulosus | Phycocelis baltica |
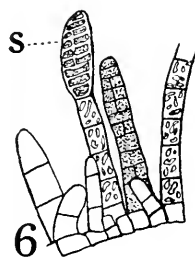
PLATE 48

Figs. 4 and 5. Portions of filaments with plurilocular sporangia. × about 300.

Fig. 6. Several filaments, *s*, a sporangium. × about 250.

3. PHYCOCELIS Stroemfelt

1. PHYCOCELIS BALTICA (Reinke) Foslie, New or Crit. Norw. Alg., 1894, p. 17. under *Myrionema.*   FIG. 6

Plants minute, epiphytic, forming small patches; basal part forming a small cellular disc composed of one or two layers of cells, some of the cells often entering the tissue of the host; erect filaments from several cells to several mm. long, monosiphonous or rarely branched; chromatophores irregularly band-like; plurilocular sporangia sessile or stalked, usually terminal but rarely lateral, mostly composed of a single vertical row of cells.

Common on the basal parts of *Desmarestia ligulata* f. *herbacea* and *Desmarestia aculeata.* Perhaps more than one species will be found by a more careful study of our specimens.

4. SPHACELARIA   Lyngbye

1. SPHACELARIA RACEMOSA Grev. Scot. Cryt. Fl. 2:96.   FIG. 7

Plants composed of a small basal mass of cellular tissue from which
arise tufts of polysiphonous filaments.   Filaments much branched, termi-
nated by a large apical cell which by transverse and longitudinal divisions
produces the cells of the polysiphonous filaments; sporangia on short few-
celled lateral branches.

The species has not been found but var. *artica* has been reported from
the west coast of Whidby Island by Gardner (14).

5. STRIARIA   Greville

1. STRIARIA ATTENUATA Grev. (1830) Crypt. Fl. Synops. p. 44.   FIG. 9

Plants filamentous, one to four dm. long, attached by a disc; branches
opposite or alternate, one to five mm. in diameter, somewhat hollow, taper-
ing into hair-like filaments at both ends; sporangia in groups forming trans-
verse lines on the thicker filaments.

Reported from Oreas Island by Lyall in Harvey's (5) report, p. 167.

| Sphacelaria | Dictyosiphon | Striaria |
| racemosa | Chordaria | attenuata |
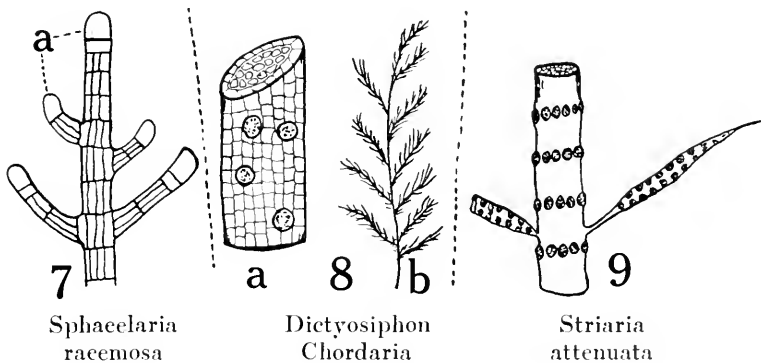
PLATE 49

Fig. 7.   Diagram of the end of a branching filament with apical
cells (a).   × about 75.

Fig. 8.   a, Diagram of part of filament showing scattered groups
of sporangia; × about 25.   b, Portion of branching filament; × about
0.25.

Fig. 9.   Diagram of portion of a filament with groups of sporangia
in transverse rows.   × about 15.

6. DICTYOSIPHON Greville

1. Dictyosiphon Chordaria Aresch. Phyc. Scand. p. 372, pl. 8.   Fig. 8

Plants filamentous, one to three dm. long; much branched; central filament and main branches usually more or less hollow below, solid above; sporangia scattered, not in groups forming transverse lines.

Reported from Friday Harbor by Setchell and Gardner (14), p. 248, growing on rocks in the middle and lower littoral zone.

7. DESMARESTIA Lamouroux

Plants filamentous, compressed or much flattened, pinnately branched, coriaceous or membranaceous, solid. Central strand or axis composed of one or several rows of elongated cells surrounded by larger long cells and smaller round cells; cortical layer composed of somewhat rounded cells. Tips of young branches ending in a delicate pinnately branched filament. Reproduction very little known; unilocular sporangia known only in some species, developing directly from cortical cells.

KEY TO SPECIES

A. Branches much flattened, blade-like, with a midrib.   1. *D. ligulata*
AA. Branches terete or compressed, not flattened.   2. *D. aculeata*

1. Desmarestia ligulata (Lightf.) Lamour. Essai. p. 25.   Fig. 10

Plant 50 cm. to 3 meters long; holdfast a small disc; stipe short, gradually widening into a central blade 5 to 100 cm. wide; branches opposite, about as wide as the central blade, flattened, with a delicate vein in the middle, somewhat serrate at edge, tapering toward both ends.

This is a variable species, the species being less common than the wider and larger form, *D. ligulata f. herbacea,* which is less branched but has larger blades.

Common on stones, shells and holdfasts of large kelps in the upper sublittoral zone.

2. Desmarestia aculeata (L.) Lamour. Essai. p. 25.   Fig. 11

Plant filamentous, five to twenty dm. long; filaments two to four mm. in diameter, terete below, much compressed above; central part of main axis and branches traversed by an articulated filament; stipe and main branches long and narrow; branches usually alternate, sometimes opposite; younger branches margined with tufts of delicate hairs which later fall off and are replaced by two rows of spines.

The younger plants are pale brown but older plants get darker. The plants lose their brown color and turn green soon after they are removed from salt water.

The form *D. aculeata f. media* has opposite terete branches and is often found with the species. Young specimens of this form have been reported as *Desmarestia viridis* (Mueller) Lamour. (9). A careful comparison of both *D. viridis* and *D. aculeata* shows that they probably all belong to the latter, at least none of them possess the characteristics of *D. viridis.*

Common in the upper sublittoral zone.

Desmarestia
ligulata

Desmarestia
aculeata
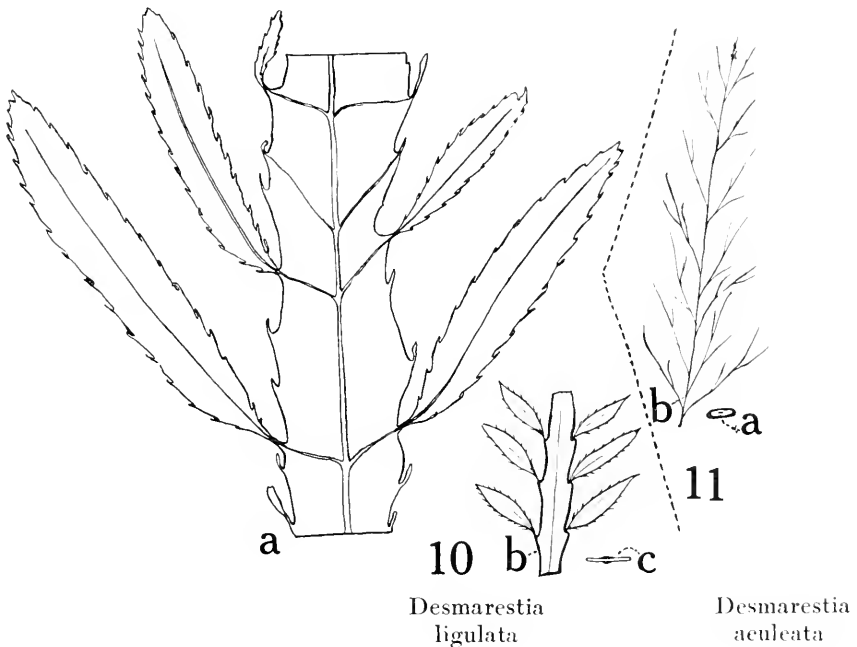
PLATE 50

Fig. 10.   a, Part of a plant of the form *herbacea;* ×0.1.   b, Part of plant; × 0.5.   c, Cross section of main axis of a plant; × 0.5.

Fig. 11.   a, Cross section of compressed filament; × 1.   b, Sketch of a plant; × 0.05.

8. AGARUM (Bory) Postels & Ruprecht

Plant with distinct holdfast, stipe and blade; holdfast composed of branching hapteres; stipe short, flattened or only flattened above; blade crinkly, perforated, ruffled along the edge; midrib broad, like a smooth band running through the middle of the blade.

KEY TO SPECIES

A. Blade fan-shaped; stipe not fimbriate, cylindrical below.

1. *A. cribrosum*

AA. Blade oblong; stipe fimbriate, flattened.   2. *A. fimbriatum*

1. AGARUM CRIBROSUM Bory Dict. Class. 9: p. 192; (*Agarum Gmelini* Mert., in Linnaea 4: p. 51.)   FIG. 12

Holdfast composed of several strong branching hapteres; stipe cylindrical, slightly flattened above, one to five cm. long, three to ten mm. wide; blade fan-shaped, wider than long, forty to sixty cm. wide, twenty to forty cm. long; margin of blade ruffled and folded especially near the base; perforations large, undulated, distributed regularly over the blade; midrib broad, flat, one to two cm. wide.
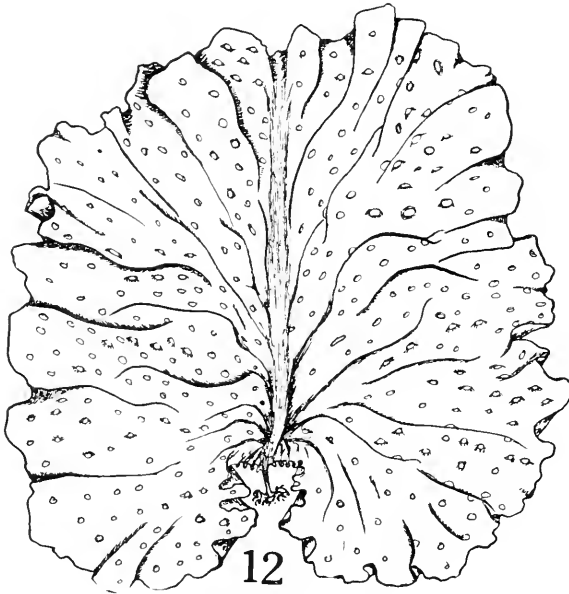
Agarum cribrosum

PLATE 51

Fig. 12.   Sketch of typical plant.   × 0.2.

Without doubt the specimens here referred to *Agarum cribrosum* are distinct from *Agarum fimbriatum* Harv. and belong to the *Agarum cribrosum* (Mert.) Bory mentioned by Setchell (15), p. 154, in which he includes *Agarum Turneri* Post. & Rupr. (10), p. 12, pl. 22, and *Agarum Gmelini* Mert., in Linnaea 4: p. 192.   The specimens under consideration

agree with *Agarum Gmelini* Mert. in their broad midrib, while *Agarum Turneri* Post. & Rupr. has a narrower and more prominent midrib. Our specimens compare well with Atlantic coast specimens No. III, *Agarum Turneri* Post. & Rupr. in Phycotheca Boreali-Americana Collins, Holden & Setchell, and also our younger stages compare with *Agarum Turneri* Post. & Rupr. in Algae Exsic. Am. Bor., Farlow, Anderson & Eaton. Our specimens also compare well with the *Agarum Gmelini* Mert. described and illustrated by Saunders (13), p. 430, pl. 61, which belongs under *Agarum cribrosum* Bory according to Setchell (15), who places all North American forms except *Agarum fimbriatum* under this species.

Young specimens about one cm. long resembling *Laminaria* were found, and intermediate stages between these and larger specimens showed that the end of the blade frays away while the plant is still young, the shape of the blade soon becoming fan-like. *Agarum fimbriatum* plants under similar conditions hardly ever fray away at the tip until they are several dm. or more long, and by that time they are two or three times as long as wide.
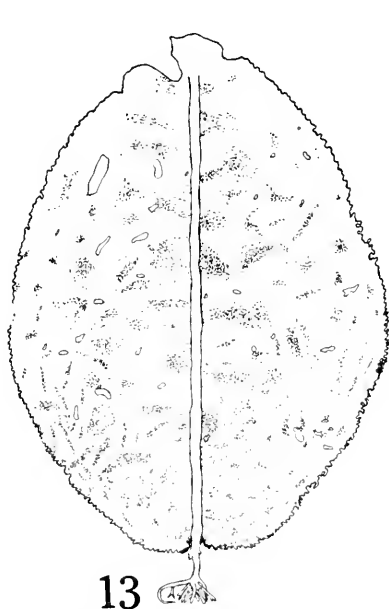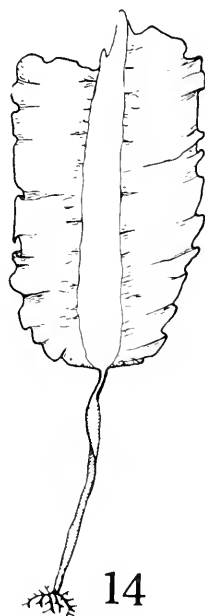
Agarum fimbriatum   Pleurophycus Gardneri

PLATE 52

Fig. 13.   Sketch of typical plant.   × about 0.1.
Fig. 14.   Sketch of plant.   × about 0.07.

As far as available literature shows this is the first station in which *Agarum cribrosum* has been reported south of Alaska. Professor Setchell informed me that this is farther south than any locality from which he has been able to examine specimens.

Forming dense zones on nearly vertical ledges about one to four meters below low tide line on the east end of Minnesota Reef, Pear Point, and Eagle point, all on San Juan Island; Canoe Island; dredged in 5 fathoms in Kansas Cove. Muenscher (8), p. 61, pl. 10, (9).

2. AGARUM FIMBRIATUM Harv. Coll. Alg. N. W. Coast, p. 166. FIG. 13

Holdfast of many branching hapteres; stipe two to ten cm. long, flattened, fimbriate, often with hapteres along the edges; blade about one meter long, crinkly, sparingly perforated; midrib about two cm. wide, running to the tip of the oblong blade.

Common on stones and rocks in the upper sublittoral zone.

9. PLEUROPHYCUS Setchell & Saunders

1. PLEUROPHYCUS GARDNERI Setchell & Saunders, Saunders in Wash. Acad. Sci. 3: p. 427, pl. 52.   FIG. 14

Holdfast of several whorls of stout branching hapteres; stipe three to seven dm. long, solid, terete at the base, much flattened above and gradually passing into the broad midrib; blade broad, linear or oblong in outline, tapering below, seven to ten dm. or more in length, 12 to 50 cm. in width, thin and soft, wrinkled or somewhat regularly pleated near the midrib; midrib three to twenty cm. wide, flat, narrow above and below.

On rocks in the upper sublittoral zone where the currents are swift.

10. COSTARIA Greville

1. COSTARIA COSTATA (Turner) Saunders, Bot. Gaz. 20: p. 57, 1895; (*Costaria Turneri* Post. & Rupr., Illustr. Alg.)   FIG. 15

Holdfast of branching hapters; stipe short, flattened, without mucilage ducts; blade broad, with five or rarely three longitudinal ribs projecting on one side only and alternating on the two surfaces, bullate and sometimes perforated, from one to two meters long, the end usually torn away.

Common in the upper sublittoral and sometimes in the lower littoral zone.

11. LAMINARIA Lamouroux

Plant consisting of holdfast stipe and blade; holdfast of branched hapteres; stipe well developed, terete or compressed, solid; blade without midrib, entire or split longitudinally, smooth or with several rows of folds.

15

Costaria costata

16
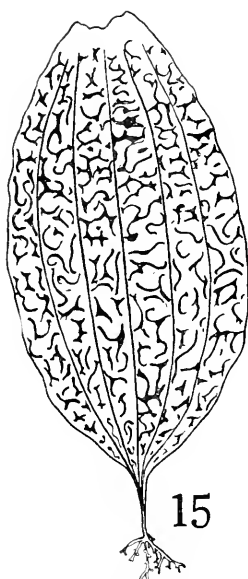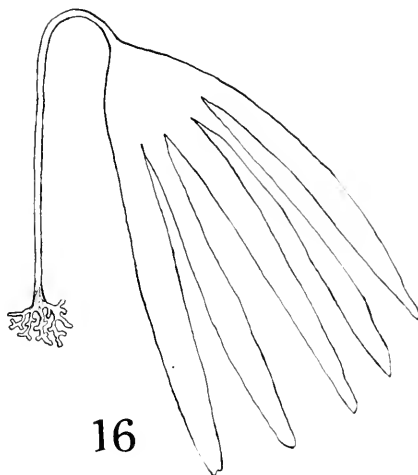
Laminaria Andersonii

PLATE 53

Fig. 15. Sketch of plant. $\times$ 0.1 to 0.05.
Fig. 16. Diagrammatic sketch of plant. $\times$ about 0. 1.

KEY TO SPECIES

A. Mucilage ducts lacking in the stipe, present in the blade.
  B. Stipe cylindrical; blade simple, thin, light brown. 1. *L. saccharina*
  BB. Stipe flattened above; blade usually split, thick, dark brown.
    2. *L. complanata*
AA. Mucilage ducts present in both stipe and blade.
  C. Stipe long, cylindrical, or compressed only toward the apex; blade split, smooth, without 2 rows of folds. 3. *L. Andersonii*
  CC. Stipe short, flattened from shortly above the base; blade entire or split, usually with 2 rows of folds. 4. *L. bullata*

1. LAMINARIA SACCHARINA (L.) Lamour. Essai. p. 22. FIG. 17

    Holdfast composed of branched hapteres forming a cone-shaped mass; stipe terete, solid, one to six cm. long, spreading above into the broad blade; blade more or less flat or folded, undulate, about one to two meteres long, two to six dm. wide, thin and light brown in color; mucilage ducts present in blade only.

    The species is common in the upper sublittoral zone. The two forms *L. saccharina f. linearis* and *L. saccharina f. membranacea* also occur in this region.

2. Laminaria complanata Setchell & Gardner, Algae of N. W. Amer.,
    p. 26, under *Laminaria saccharina f. complanata.*   Fig. 19

Holdfast composed of branched hapteres; stipe two to five dm. long,
terete below, flattened above, without mucilage ducts; blade about one
meter long and 50 cm. wide, ample, ruffled, base decidedly cordate; mu-
cilage ducts large and abundant just under the surface cells of the blade.

Known only from the sublittoral zone in a few quiet localities.   Type
locality, Friday Harbor, Washington.

3. Laminaria Andersonii Farlow, in Anderson Calif. Marine Algae. Zoe.
    2: p. 220. 1891.   Fig. 16

Holdfast composed of branched hapteres; stipe cylindrical or com-
pressed at apex, about one to three dm. long, gradually merging into the

Laminaria saccharina   Laminaria bullata   Laminaria complanata
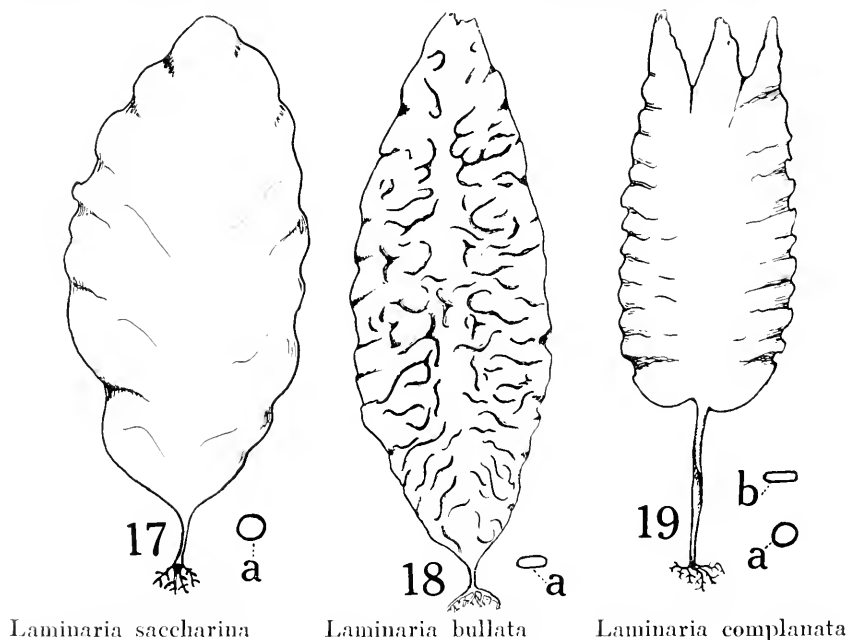
PLATE 54

Figs. 17 and 18. Diagrammatic sketch of plant; × about 0.05.
a. Cross section of stipe; × 0.5.

Fig. 19. Diagrammatic sketch of plant; × about 0.07.   a, Cross
section of upper part of stipe; b, cross section of lower part of stipe;
× 0.5.

blade; blade vertically split into several long segments; mucilage ducts present in both stipe and blade.

Infrequent on rocks in the upper sublittoral zone.

4. LAMINARIA BULLATA Kjellman, Om Beringhafvets Algflora. p. 46. 1889.
                                                                    FIG. 18

Holdfast or branched hapteres; stipe terete at extreme base, much compressed above, one to ten cm. long; blade very variable in size and shape, long, narrow or broad, entire or split lengthwise, with two longitudinal rows of crossfolds or bullae in the margins, dark brown and rather thick; mucilage ducts present in both stipe and blade.

A very variable species represented more commonly by several forms common on rocks in the lower littoral and upper sublittoral zones. Some specimens show distinct characteristics of *f. amplissima*, *f. angusta* and *f. subsimplex* of Setchell & Gardner (14). The occurrence of so many intermediate forms suggests the possibility that many of the forms under this species may be variations due to differences in age and habitat.
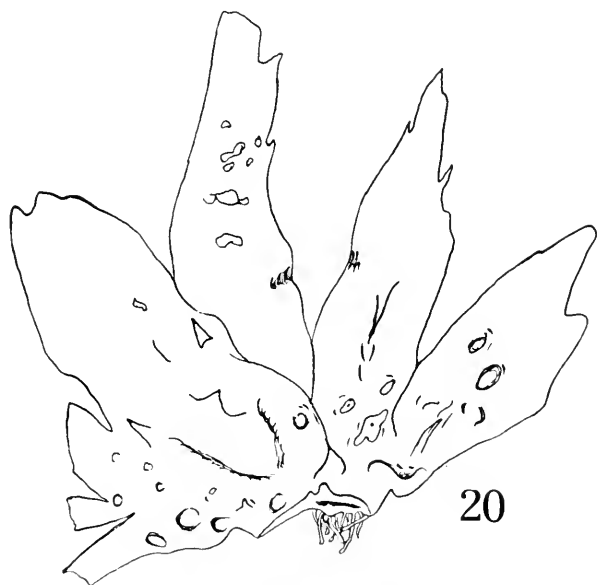
Hedophyllum sessile

PLATE 55

Fig. 20.   Sketch of plant.   (After Saunders.)   × 0.2.

12. HEDOPHYLLUM   Setchell

Holdfast composed of branched hapteres; stipe at first short, later disappearing; blade at first entire and regular, later becoming irregular and much split up, thick, mucilaginous, its surface plane or very irregular; blade in older plants wearing away in the middle until it has the appearance of several irregular blades which send out hapteres from their creeping rhizome-like bases.

The genus *Hedophyllum* as Setchell (14) has already pointed out, is not entirely satisfactory.   Good specimens in various stages of development are needed for further study.

1. HEDOPHYLLUM SESSILE (Agardh) Setchell, Zoe 5: p. 122; (*Laminaria sessilis* Ag. Syst. Alg. p. 270).   FIG. 20

Holdfast composed of short closely crowded branched hapteres which usually come from the base of the blade; stipe very short and flattened in young plants but soon disappearing as the plants get older; blade at first ovate and entire but soon becoming irregular and much split, sessile, bullate or rarely smooth; mucilage ducts numerous and large.

Forming dense beds near the low tide line on exposed shores.

2. HEDOPHYLLUM SUBSESSILE (Aresch.) Setchell, Zoe 5: p. 123; (*Laminaria Bongardiana subsessilis* Aresch., Obs. Phyc. 4: p. 5.)   FIG. 21

Holdfast composed of branched hapteres; stipe short, stout, somewhat flattened, later disappearing; blade at first narrow and simple, then broader and divided, finally with cordate base and marginal rows of bullate swellings; mucilage ducts large and frequent. In older plants the central portion of the blade dies away to the base and forms two blades connected by the margin of the old blade which sends out hapteres and forms a rhizome-like holdfast.

This species is not known to the writer from this region. Saunders (13), p. 430, reports it as common in exposed places from Puget Sound northward. The specimens referred to this species (8), p. 70, belong to a much split form of *Laminaria bullata*.

21

Hedophyllum subsessile
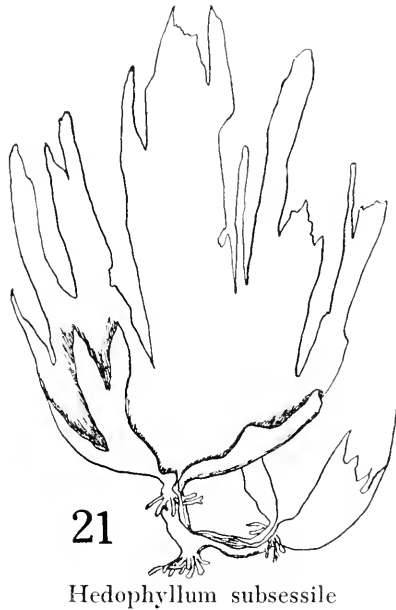
PLATE 56

Fig. 21.   Sketch of plant. (After Setchell.) $\times$ about 0.2.

13. CYMATHERE J. Agardh

1. CYMATHERE TRIPLICATA (Post. & Rupr.) J. Ag. De Laminariis p. 29;
(*Laminaria triplicata* Post. & Rupr., Illustr. Alg. p. 10).   FIG. 22

Holdfast a solid conical disc about two to three cm. in diameter; stipe
exceedingly short, about five cm. in length; blade long and narrow, one
to four meters long and one to two dm. wide, usually entire but some-
times splitting into strap-like segments at the tip; surface of blade very
smooth, plicate, with three to five longitudinal ridges and grooves which al-
ternate on the upper and lower surfaces.

In the lower littoral zone on wave-beaten shores; sometimes dredged
from gravel and shells in the upper sublittoral zone.

14. PHYLLITIS Kuetzing

1. PHYLLITIS FASCIA (Mueller) Kuetz. Phyc. Gener. 3: 342, pl. 24; (*Lam-
inaria fascia*, Ag. Sp. 1: p. 122).   FIG. 23

Plant body a solid membranaceous, lanceolate or linear blade, tapering
toward the base to a short rounded stalk; blade composed of two layers
of tissue, the cortical layer of small cuboidal cells, the inner layer of oblong

colorless cells.   Plants single or in clusters arising from a small disc-like base.

Rare; on stones in the lower littoral zone.

22   23   24

Cymathere triplicata   Phyllitis fascia   Punctaria latifolia
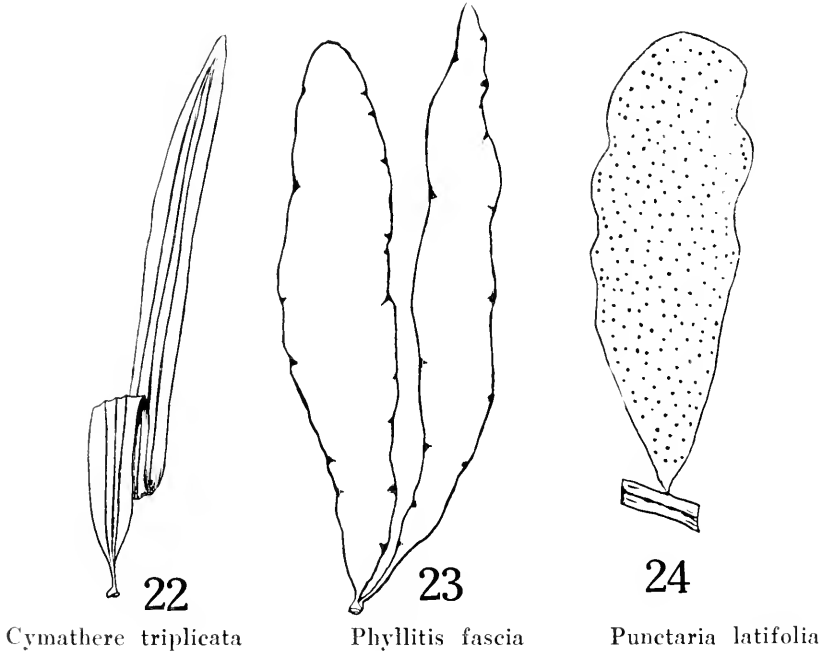
PLATE 57

Fig. 22.   Diagrammatic sketch of plant.   ✕ about 0.05.

Figs. 23 and 24.   Diagrammatic sketches of the plants.   ✕ about 0.25.

15. PUNCTARIA   Greville

1. Punctaria latifolia Grev. Alg. Brit. p. 52.   Fig. 24

Plant body an undivided flat olive-green Ulva-like blade, oblong or obovate, suddenly tapering below into a short stalk.   Blade usually composed of four layers of cells and covered by distinct minute dots in which the sporangia are produced.   Plants sometimes in groups.

In the lower littoral zone on other algae.

16. SORANTHERA   Postels & Ruprecht

1. SORANTHERA ULVOIDEA Post. & Rupr. Illustr. Algar. p. 19.   FIG. 25
 Plant body a brown inflated sac, usually oval or nearly round; sac composed of two layers of tissue, the inner of large nearly colorless cells, the cortical layer of small colorless cells. Sori very abundant and evenly distributed over the surface of the plant.
 Usually growing on *Rhodomela Larix* or *Odonthalia* ssp. near the low tide line on somewhat muddy shores.

17. COILODESME   Stroemfelt

 Plant body hollow, cylindrical or oval; stipe very short and inconspicuous; holdfast minute, disc-like. The expanded sac composed of two or three layers of tissue, the inner layer of large mostly colorless cylindri-
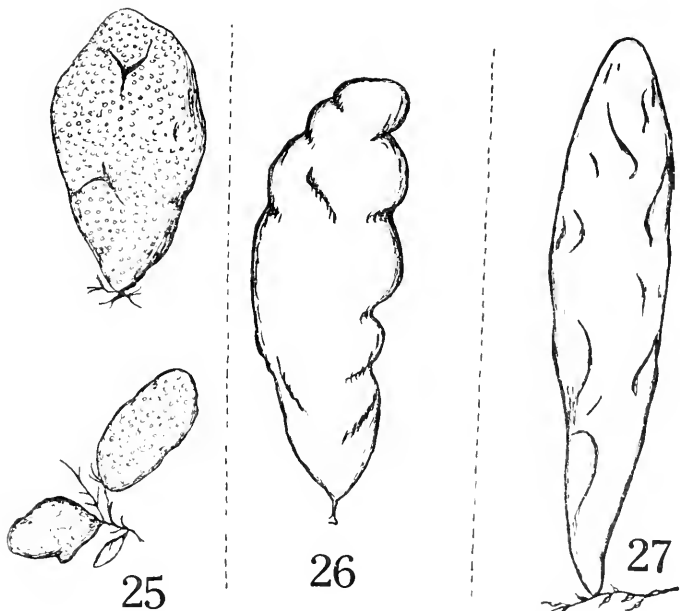
Soranthera ulvoidea   Coilodesme bulligera   Coilodesme californica

PLATE 58

 Fig. 25.   Sketch of large and small plants, attached to *Rhodomela Larix*. $\times$ 1.
 Fig. 26.   Sketch of plant. $\times$ 0.5.
 Fig. 27.   Sketch of plant on *Cystophyllum geminatum*. $\times$ 0.5.

cal cells, the outer layer of smaller colored cells. Unilocular sporangia solitary, scattered, developed from the outer layer of cells; pluriocular sporangia and paraphyses wanting.

<div align="center">KEY TO SPECIES</div>

A. Plants growing on *Cystophyllum geminatum.*   1. *C. californica*
AA. Plants growing on rocks.   2. *C. bulligera*

1. COILODESME CALIFORNICA (Rupr.) Kjell. in Engl. & Prantl Natürl.
    Pflanzenfam. 86 Lief. p. 204.)   FIG. 27
    Plant body dark brown, hollow, inflated, thin membranaceous. cylindri-
cal, or sometimes ovoid, usually collapsed; the lower part of the sac
gradually tapering into a short stalk; the upper part of the sac usually
torn away in older plants.
    On *Cystophyllum geminatum* in the upper sublittoral zone.

2. COILODESME BULLIGERA Stroemf. Isl. Algveget. p. 48, pl. 2.   FIG. 26
    Plant body like the preceding but the inflated sac is more swollen and
bullate around the edges, somewhat smaller than the preceding, about one
dm. or less long.

28
Colpomenia sinuosa

29
Leathesia difformis
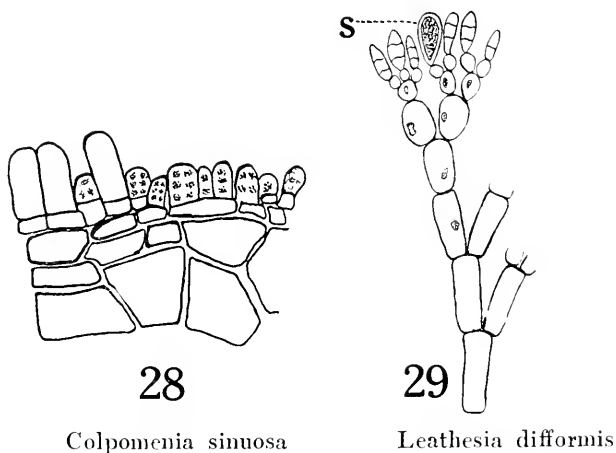
<div align="center">PLATE 59</div>

Fig. 28.   Diagrammatic sketch showing solid layers of cells making
up the irregular hollow mass of the plant body. $\times$ about 200.

Fig. 29.   Sketch showing dichotomously branching rows of cells
making up the irregular hollow mass of plant body; *s*, sporangia. $\times$
about 200.

This plant can be distinguished from *C. californica* because it grows on rocks in the lower littoral zone and not on *Cystophyllum* as the former species. Uncommon; on Hankin Point, Shaw Island.

18. COLPOMENIA   Derbes & Solier

1. Colpomenia sinuosa (Roth) Derb. & Sol. Mem. Phys. Alg. p. 11, pl. 22.   Fig. 28

Plant body a sessile, globose or oval thin sac, usually filled with water when young; older plants forming hollow irregular masses two to ten cm. across. Wall of the sac composed of two layers of tissue; inner layer consisting of a few large rounded colorless cells; outer layer of small quadrangular colored cells.

Uncommon; on rocks where they are exposed only at extreme low tide, seldom on other algae.

19. LEATHESIA   Gray

1. Leathesia difformis (L.) Aresch. Phyc. scand. p. 376.   Fig. 29

Plant body a sessile, globose or very irregular sac-like mass often more or less solid when young but becoming hollow with age. Central part of plant composed of repeatedly branched filaments which finally terminate in the outer layer of more or less cubical cells, paraphyses and sporangia.

This plant is very often mistaken for *Colpomenia* but can usually be told from the latter by its thicker plant body and light brown color. However, a microscopic examination is often necessary to separate these two genera.

Common on other algae especially *Rhodomela Larix* and *Fucus evanescens* in the lower littoral zone.

20. SCYTOSIPHON   Agardh

1. Scytosiphon lomentarius (Lyngbye) J. Ag. Sp. 1: p. 126.   Fig. 30

Plant body unbranched, tubular, one to eighteen dm. long, two to ten mm. thick; constrictions in tube regular and frequent or rarely almost entirely wanting; sporangia almost covering the entire surface of the tube.

On rocks and stones in the lower littoral zone.

21. MYELOPHYCUS   Kjellman

1. Myelophycus intestinalis Saund., Proc. Wash. Acad. Sci. 3: p. 420, pl. 67.   Fig. 31

Plant cylindrical, hollow, more or less twisted, not constricted; one to three dm. long, narrowed into a solid stipe at the extreme basal end;

sporangia very abundant, scattered irregularly throughout the surface of the tube-like plant body.

In quiet coves according to Saunders (13) p. 420.

<center>22. MYRIONEMA   Greville</center>

1. MYRIONEMA STRANGULANS Grev. Crypt. Fl. p. 300.   FIG. 32

Plants forming small dark-brown patches on other algae, five to ten mm. or more in diameter; composed of a flat layer of decumbent cohering filaments from which arise the short, simple erect filaments; sporangia on short stalks or sessile between the erect filaments.

Growing on *Ulva Lactuca* and other algae in the lower littoral zone.

Scytosiphon lomentarius

Myelophycus intestinalis

Myrionema strangulans

Ralfsia verrucosa
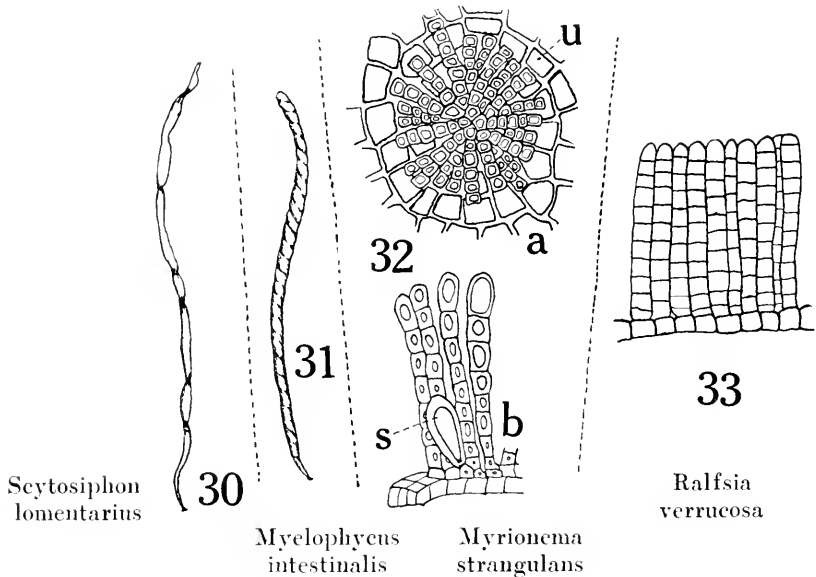
<center>PLATE 60</center>

Fig. 30.   Sketch of plant.   × about 0.25.

Fig. 31.   Sketch of plant. (After Saunders.)   × about 0.25.

Fig. 32.   a. Sketch of a top view of a "patch" on *Ulva Lactuca; u, Ulva* cells; b. sketch showing rows of cells; s, sporangium.   × about 400.

Fig. 33.   Diagram of a vertical section through a thallus showing closely connected filaments.   × about 400.

23. RALFSIA Berkeley

1. RALFSIA VERRUCOSA (Aresch.) J. Ag. Sp. 1: p. 62.   FIG. 33

Plants forming dark brown or black crustaceous expansions of indefinite extent resembling tar spots; composed of a horizontal layer of cells from which arise the short vertical filaments which are united to each other forming a solid cushion-like mass; sporangia in sori over the surface of the plant.

Common, forming dark brown spots on rocks in tide pools and in the lower littoral zone. It is possible that not all of our specimens belong to this species.

24. NEREOCYSTIS Postels & Ruprecht

1. NEREOCYSTIS LUETKEANA (Mertens) Post. & Rupr. Algar. p. 9.
        FIG. 34

Holdfast of many branched hapteres forming a dense cluster about one or two dm. in diameter; stipe from three to fifteen meters long,

Nereocystis   Egregia   Macrocystis
Luetkeana   Menziesii   pirifera
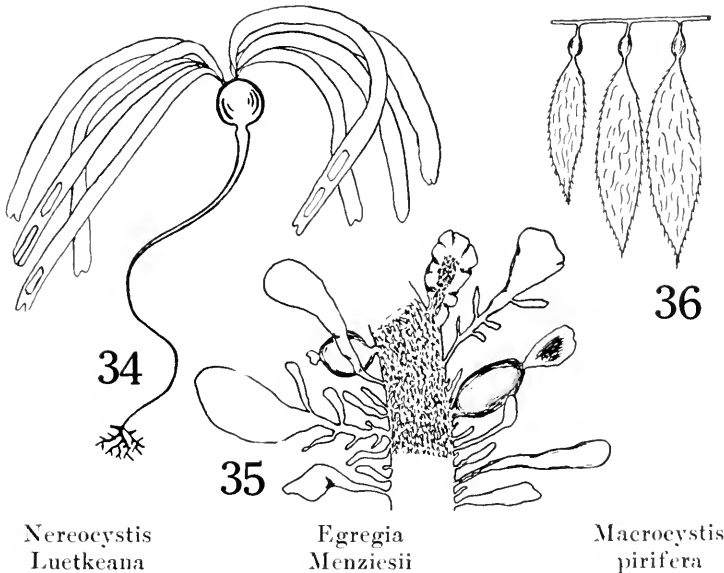
PLATE 61

Fig. 34. Diagrammatic sketch of plant showing general form of plant. × about 0.01, but parts are not quite in proportion.

Fig. 35. Sketch showing a portion of a flattened branch with small air bladders and several kinds of blades. × about 0.33.

Fig. 36. Sketch of a portion of a branch showing several blades with basal air bladders. × about 0.07.

tapering, whip-like, solid below and hollow above, gradually getting larger near the top but slightly constricted just below the nearly round air-bladder; blades usually about twenty or more, coming from a single blade by longitudinal splitting, in two groups on end of air bladder, long and narrow, about three to eight meters long and five to fifteen cm. wide; sori forming large dark brown patches on the blades.

Common in large beds along rocky shores.

25. EGREGIA   Areschoug

1. EGREGIA MENZIESII (Turner) Aresch. in Bot. Not. 1876.   No. 3. p. 66: (*Fucus menziesii* Turner, Hist. Fuc. p. 57.)   FIG. 35

Holdfast of many branching hapteres which in older plants form a disc about one dm. in diameter; stipe nearly terete for about two to four cm. and then dividing into several flattened strap-like branches, stipe with its branches several meters long; blades many, along each side of the branches, usually small and variable in form, of four kinds as follows: (a) spatulate or ovate, (b) branched, (c) bladder-bearing, and (d) short cuneate, sori-bearing.

Near low tide mark on rocks of surf-beaten shores.

26. MACROCYSTIS   Agardh

1. MACROCYSTIS PIRIFERA (Turner) Agardh. Sp. 1: p. 46.   FIG. 36

Holdfast rhizome-like, with many branching hapteres; stipe several to many meters long, branched into several long unequal parts; blades many on the upper part of the plant, with wrinkled surfaces and serrate edges; bladders many, one on the base of each blade except the terminal ones.

A large kelp forming beds along the rough rocky shores near Neah Bay (11). Occasionally found drifted ashore on the islands of Puget Sound.

27. FUCUS   (Tournefort)   Linnaeus

Holdfast a disc; stipe cylindrical, gradually merging into the flattened blade-like body; branches dichotomous, flattened, ribbed below, often plane above, rarely with air bladders; antheridia and oogonia on the same plant, in sunken conceptacles in terminal receptacles; oogonium with eight eggs.

KEY TO SPECIES

A. Receptacles broad, swollen.   1. *F. evanescens*
AA. Receptacles long, narrow, flattened.   2. *F. inflatus*

1. Fucus evanescens Agardh Sp. 1. p. 92. (Farlow, Algae of New
England, p. 101.)   Fig. 37
    Plant repeatedly dichotomously branched, several dm. long; branches
with distinct midrib below, wider and scarcely visible above, margin
broad, entire, somewhat wavy; bladders usually wanting; receptacles
swollen, broad, usually united in pairs, sometimes with a small margin
along the edges.
    Very common in the littoral zone. The wider typical forms are most
common but in certain places forms with narrow branches are rather
frequent.

2. Fucus inflatus (L.) Vahl Fl. dan. tab. 1127.   Fig. 38
    Plant regularly dichotomously branched, three to nine dm. long;
branches with a distinct midrib below, invisible above, margin wanting
or when present very narrow and smooth; bladders usually wanting,

| Fucus | Fucus | Pelvetiopsis | Pelvetia |
| evanescens | inflatus | limitata | fastigiata |
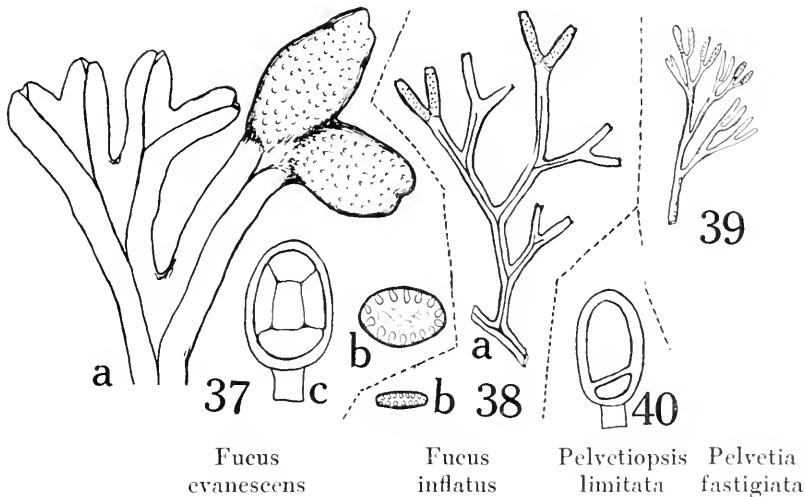
PLATE 62

    Fig. 37.   a, Portion of branch with receptacles; b, diagram of cross
section through a receptacle; × 0.33. c, Diagram of vertical section of
oogonium; × about 300.
    Fig. 38.   a, Portion of branch with receptacles; b, diagram of cross
section through a receptacle. × 0.33.
    Fig. 39.   Portion of branch with receptacles. × 0.33.
    Fig. 40.   Diagram of vertical section of oogonium. × about 300.

when present forming indefinite elongated inflations; receptacles flat, long and narrow, often forked.

In the upper littoral zone. This species is represented by several forms varying in width from linear forms to those about as wide as the narrow forms of *F. evanescens.*

28. PELVETIA   Decaisne & Thuret

1. Pelvetia fastigiata Decne.; (*Fucoidium fastigiatum* J. Ag. Spec. 1: p. 203.)   Fig. 39

Plants about ten to thirty cm. long; holdfast disc-shaped, about one cm. across; stipe branched dichotomously from just above the base, main part short, elliptical in cross section; blades many, on the ends of the branches of the stipe, without midrib; tips of blades forming two swollen mucilaginous receptacles on which are found the small wart-like conceptacles; oogonium usually containing two equal eggs.

Miss Tilden's report, and the similarity of the genus to *Pelvetiopsis* in general appearance and habitat, are the reasons for the inclusion of the species.

In the littoral zone on rocks that are exposed to the spray. Found on the west coast of Vancouver Island by Professor Tilden (16) No. 233.

29. PELVETIOPSIS   Gardner

1. Pelvetiopsis limitata (Setchell) Gardner, Univ. Calif. Publ. 4: p. 127; (*Pelvetia fastigiata f. limitata* Setchell, in Collins, Holden & Setchell, Phyc. Bor. Am.)   Fig. 40

Plant about ten cm. long; holdfast an irregular disc; stipe branched dichotomously from just above the base forming a cluster of branches; blades many, on the ends of the branches of the stipe, without midrib; tips of the blades forming two swollen or somewhat flattered mucilaginous receptacles; oogonium containing two unequal eggs.

Gardner (3,4) separates *Pelvetiopsis* from the genus *Pelvetia* because in the former the two eggs in the oogonium are very unequal in size while in the latter genus the two eggs are equal in size. The external appearance of the two genera is very similar.

On rocks in the upper littoral zone. Gardner (3) gives the range of this species from Vancouver Island to California; therefore it is included in this region.

30. CYSTOPHYLLUM   J. Agardh

1. Cystophyllum geminatum (Ag.) J. Ag. Sp. 1, p. 232.   Fig. 41

Holdfast a conical disc; plant body very much branched; lower branches short, flat and blade-like; upper branches long, terete, at times

almost filamentous, with one or more small vesicles or air bladders near the tip; conceptacles just below the vesicles on short branches.

Common in the upper sublittoral zone. *Coilodesme Californica* often grows on this plant.

Cystophyllum   Postelsia
geminatum   palmaeformis
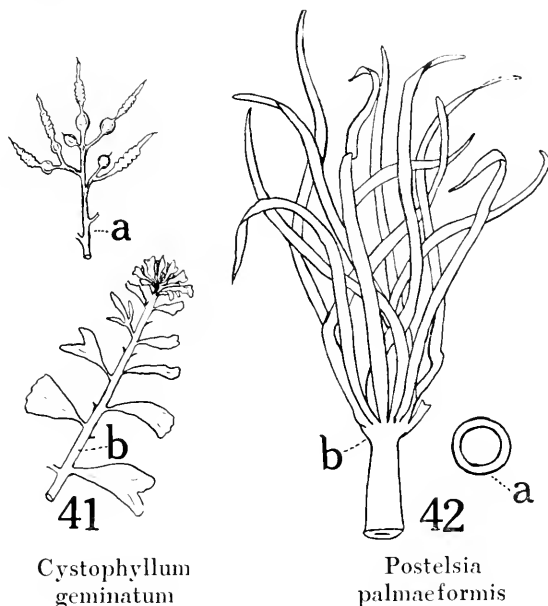
PLATE 63

Fig. 41. a, Branch from upper portion, with small air bladders terminated by receptacles; b, branch from lower part of plant, showing small blades. $\times$ 0.5.

Fig. 42. a, Cross section of hollow stipe; $\times$ 0.33. b, top of plant with group of blades; $\times$ 0.2.

31. POSTELSIA Ruprecht

1. POSTELSIA PALMAEFORMIS Rupr. Pflanzen aus dem nördl. Th. des Stillen
   Oceans. p. 19, pl. 8.   FIG. 42

Holdfast of thick branching hapteres; stipe unbranched, stout, hollow, about two to four dm. long; blades from sixteen to thirty-two, narrow, furrowed, borne on the end of the stipe; sori in the furrows.

Growing on rocks along shores exposed to heavy surf.

32. ALARIA Greville

Holdfast of stout or slender branching hapteres; stipe solid, terete or flattened, with or without mucilage ducts; blade terminal, elongated,

thin, with a distinct midrib; sporophylls on both sides of the rachis, long or short, broad or narrow, of definite growth; sorus almost covering both surfaces of the mature sporophyll.

The species of *Alaria* in this vicinity are in need of further study in order to straighten out some of the difficulties confronted in determining the species. The length and width of stipe, blade, midrib and sporophylls have been used as the basis for separating several so-called species. The occurrence of so many intermediate stages or forms compared with the few specimens that really answer the specific descriptions have led the writer to include our specimens of *Alaria* at least for the present, in two species, *A. tenuifolia* and *A. valida*.

<div align="center">KEY TO SPECIES</div>

A. Stipe much flattened.   1. *A. tenuifolia*
AA. Stipe cylindrical or flattened only above.   2. *A. valida*

1. ALARIA TENUIFOLIA Setchell in Collins, Holden & Setchell, P. B. A.
                                                                        FIG. 43

Holdfast composed of numerous branching hapteres; stipe five to eight dm. long, terete only at the very base, the rest much flattened, slender, flexible. Blade from one to four meters long, twenty-five to thirty-five cm. or more wide, very thin; midrib eight to twelve mm. wide; sporophylls when mature short and broad, cordate at the base, with rather distinct stalks, in pairs on the flattened more or less elongated rachis.

A variable species represented by several forms. Common on the boulders and stones in the upper sublittoral zone.

2. ALARIA VALIDA Kjellman & Setchell, in Setchell & Gardner's Algae of
    N. W. Am. p. 278, pl. 21.   FIG. 44

Holdfast similar to the above species; stipe three to forty cm. long, terete or flattened only above, firm; blade two to five meters long, oblonglanceolate, tapering below, somewhat undulate, plicate; midrib five to twenty mm. wide; sporophylls broad or sometimes narrow, varying in length from ten to forty cm., tip often pointed, base often cordate, with short stalks; sorus almost covering the sporophyll except for a margin around the outer edge.

Upper sublittoral zone, sometimes in the lower littoral zone.

Under the above species the writer has included *Alaria cordata* Tilden, Am. Algae 241, and *Alaria valida* Kjellman and Setchell.

So far the writer has been unable to find any of the characteristics that are supposed to separate these two species to hold constant under different conditions. According to Setchell (14) p. 278 and pl. 21, the

stipe of *Alaria valida* is from one to five cm. long if one takes his description, but according to his plate which is drawn times one-sixth it would be at least seven cm. long. According to Tilden's (16) description of *A. cordata* the stipe is from one to seven dm. long, while Saunders (13)

Alaria tenuifolia   Alaria valida
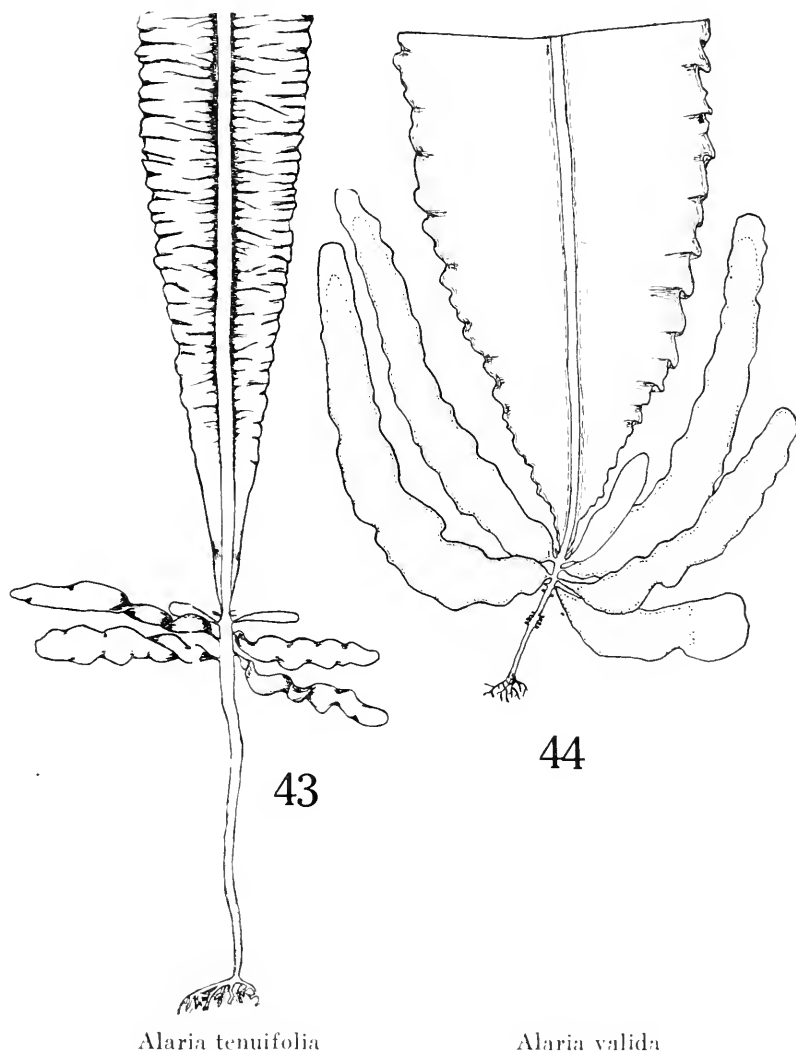
PLATE 64

Fig. 43.   Lower portion of plant. $\times$ about 0.08.
Fig. 44.   Lower portion of plant.   (After Setchell.) $\times$ about 0.08.

p. 426, says the stipe of *Alaria cordata* is fifteen cm. long. These varia-
tions show that the plants vary under different conditions and in different
localities. These variations must first be determined before definite lim-
itations can be set for the different species.

33. PTERYGOPHORA   Ruprecht

1. Pterygophora californica Rupr. Algenstämme, p. 64.   Fig. 45

Holdfast composed of stout dichotomously branching hapteres; stipe
erect, stout, two to seven cm. in diameter, solid, "woody," showing rings
in cross section, without mucilage ducts; blades smooth and leathery, one
terminal and three or more pairs lateral; terminal blade with mucilage
ducts and midrib-like thickening; lateral blades or sporophylls without
midrib; sori on lateral blades, rarely on terminal blade, forming irregular
patches on both surfaces.
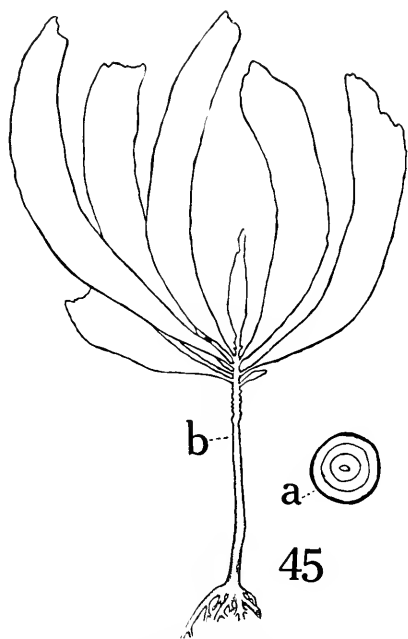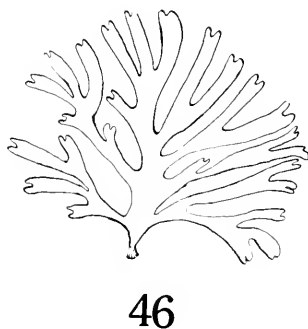
Pterygophora californica   Dilophus flabellatus

PLATE 65

Fig. 45.   a, Cross section of solid "woody" stipe showing rings;
× 0.25. b, Sketch of plant; × about 0.03.

Fig. 46.   Sketch of plant.   × 0.33.   Drawn from Collins (1),
P. B. A., No. 843.

On rocks in the littoral zone on surf-beaten shores about Cape Flattery. A number of good specimens were dredged five fathoms below low tide in Peavine Pass between Blakely and Obstruction Island in July, 1916.

34. DILOPHUS J. Agardh

1. DILOPHUS FLABELLATUS Collins, in Collins, Holden & Setchell's Phycotheca Boreali-Americana, 834.   FIG. 46

Plant body rounded in outline, composed of a densely dichtomously branched flattened thallus; branches or segments of the thallus elongate, widening upwards, with entire margin and forked or rounded tips. Young plants consisting of a single layer of large cells with a single layer of small cortical cells, older plants becoming thicker especially near the margin. Oogonia, antheridia and spores on separate individuals, at first on the middle of the segments, later covering the entire width; oogonia scattered but usually close; antheridia in oval or oblong patches; spores in patches, sometimes becoming confluent.

Chordaria abietina   Castagnea divaricata
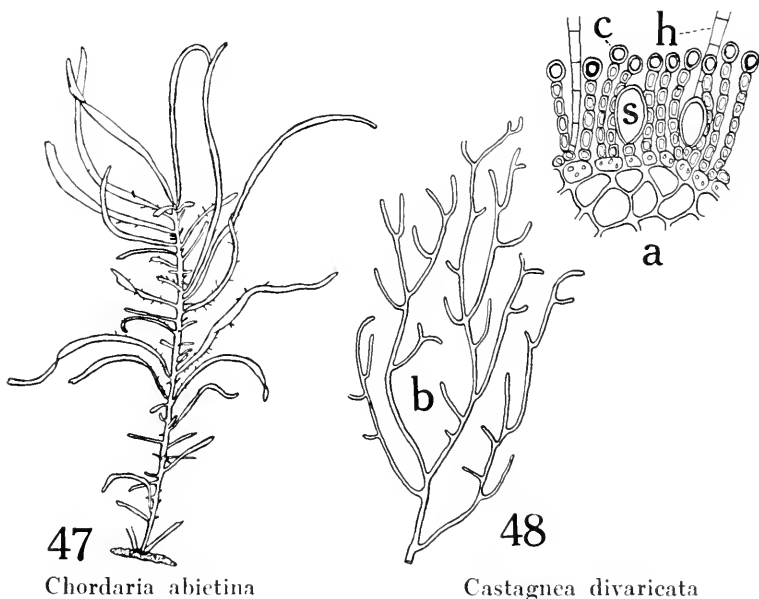
PLATE 66

Fig. 47. Plant with pad-like holdfast. $\times$ 0.25.

Fig. 48. a, Part of cross section of branch; *s*, unilocular sporangia; *h*, hyaline hairs; *c*, cortical filaments with terminal round cells; $\times$ about 200. b, Portion of plant; $\times$ 0.5.

Reported from this region from only one place by Tilden (16). Washed ashore. Near Tracyton, Kitsap County.

Tilden, American Algae No. 335, under *Dictyota dichotoma*.

Collins, Holden and Setchell, Phycotheca Boreali-Americana, No. 834.

35. CHORDARIA   C. Agardh

1. CHORDARIA ABIETINA Ruprecht, in Farlow, List of marine algae of the U. S. p. 357. 1875.   FIG. 47

Holdfast a horizontal lobed pad one to several cm. across; erect stalks single or more often several from the same holdfast; central stalk or axis one to five dm. long, with numerous lateral branches, composed of a rather solid mass of pseudoparenchymatous tissue with scattered longitudinal filaments surrounded by a solid peripheral layer becoming somewhat hollow with age; growth by apical and subterminal cells; sporangia scattered uniformly on the peripheral layer of the branches and covered by short club-shaped paraphyses.

On rocks in the lower littoral zone.

36. CASTAGNEA   Derbes & Solier

1. CASTAGNEA DIVARICATA (Ag.) J. Agardh, Till Algern System. 4: 37.
                                        FIG. 48

Plant body one to two dm. long, several mm. thick, branched, composed of a soft loosely intertangled mass of filaments which is made up of a central monosiphonous filament with many lateral branches forming a peripheral layer; growth of filaments intercalary; central filaments colorless, lateral ones with many chromatophores; unilocular sporangia oval lateral outgrowths from the upper cells of the peripheral filaments.

On mud flat, lower littoral zone. East Sound, Orcas Island. Gardner (14).

37. MESOGLOIA   Agardh

1. MESOGLOIA ANDERSONII Farlow, Bull. Torr. Bot. Club. 16:9-11. 1889.
                                        FIG. 49

Plants solitary or gregarious; thallus cylindrical in form, one to three cm. long, several mm. in diameter, repeatedly and irregularly dichotomously branched; secondary branches occasionally subpinnate, tips scarcely attenuated, clothed with projecting hairs when young; unilocular sporangia pyriform, at the base of cortical filaments, scattered uniformly over the surface of thallus.

On rocks in the lower littoral or upper sublittoral zone.

Tilden, American Algae, No. 349, under *Chordaria flagelliformis*.

Collins, Holden & Setchell, Phycotheca Boreali-Americana, No. 925.
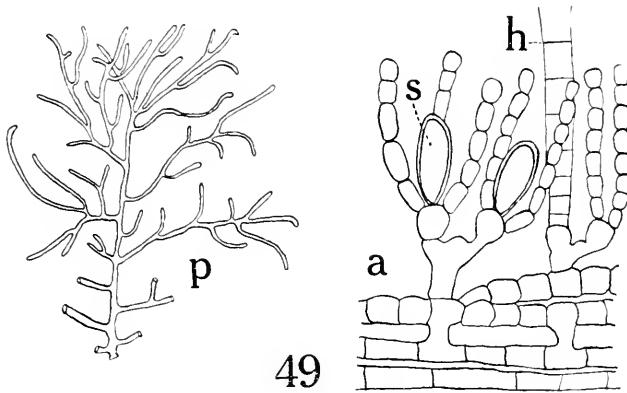
Mesogloia Andersonii

PLATE 67

Fig. 49.   *p*, Portion of plant; $\times$ 0.5.   a, Cross section of cortical region of branch; *h*, hyaline hair; *s*, unilocular sporangia; (After Farlow); $\times$ about 400.

Five species of Phaeophyceae, so far not known to occur in Puget Sound, have been reported by MacMillan (6) from the southern shore of Vancouver Island, British Columbia; namely, *Lessonia littoralis* Farlow, *Eisenia arborea* Aresch., *Thallassiophyllum clathrus* (Gmel.) P. & R., *Chorda filum* (L.) Lamour, and *Dictyoneuron Californicum* Ruprecht. It would therefore not be surprising to find these species sparingly on the rougher shores of Puget Sound, especially along the American shore of the Strait of Juan de Fuca.

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Male Reproductive Organs of Decapoda, With Special Reference to Puget Sound Forms

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CONTENTS

1. INTRODUCTORY REMARKS

In a previous publication (Fasten, 1915), the author described the male reproductive organs of the following Brachyura which occur in Puget Sound: *Cancer magister, Cancer productus, Hyas lyratus, Oregonia gracilis, Hemigrapsus nudus, Telmessus cheiragonus, Epialtus productus* and *Pugettia gracilis*. During the summer of 1916, while the author was resident at the Puget Sound Marine Station, numerous other Decapoda were collected for investigation, including the Brachyura *Cancer gracilis, Cancer oregonensis, Scyra acutifrons* and *Lophopanopeus bellus*, as well as the free living Anomura *Lopholithodes mandtii, Haplogaster mortensii, Rhinolithodes wossnessenskii* and *Petrolisthes eriomerus*. Also, the writer had on hand for comparative study, preserved material of the male reproductive organs from the Puget Sound hermit crab (*Pagurus setosus*), the Pacific coast crayfish (*Astacus leniusculus*), the Atlantic coast lobster (*Homarus americanus*), and the spiny lobster of the California coast (*Panulirus interruptus*). The material from *Pagurus setosus, Astacus leniusculus* and *Homarus americanus* was collected by the author himself, while that from *Panulirus interruptus* was obtained through the kindness of Dr. Bennet M. Allen of the University of Kansas.

The above Decapoda were studied in part at the Puget Sound Marine Station, but the bulk of the investigation was carried on in the zoological laboratories of the University of Washington during the fall, winter and spring months of 1916-1917.

2.   MALE REPRODUCTIVE ORGANS OF BRACHYURA

The male reproductive organs of *Cancer gracilis, Cancer oregonensis, Scyra acutifrons* and *Lophopanopeus bellus* closely resemble the same structures in the other Brachyura discussed in my previous paper (Fasten, 1915). These organs are located in the chamber of the cephalothorax and when fully developed they occupy the main portion of this cavity (See *Figs.* 1-4). The organs lie directly below the heart and above the digestive glands or the so-called liver. The testis (*Figs.* 1-4, *t*), which comprises the main part of the male reproductive organs, is bilobed and profusely tubular in structure. Each testicular lobe is found in the upper part of the cephalothoracic region, and extends laterally along the stomach. Both lobes unite in the median plane of the body (*Figs.* 1-4, *x*), underneath the anterior portion of the heart. Near this junction point two slender tubes (*Figs.* 1-4, *v.* d.) make their origin, the so called vasa deferentia, one tube originating from each testicular lobe. These run posteriorly to the base of the fifth pair of walking legs, where they open to the outside.

In *Cancer gracilis* (*Fig.* 1), the male reproductive organs resemble those of *Cancer productus* very closely (Compare *Fig.* 1 with *Fig.* 1 on p. 37 of Fasten, 1915). In *Cancer oregonensis* (*Fig.* 2), all parts of the male reproductive organs are massively developed. The testis (*Fig.* 2, *t*) fills in almost completely the upper lateral spaces of the cephalothorax, while the vas deferent tubes (*Fig.* 2, *v.* d.) are thick structures tightly coiled in the chamber between the heart and the intestine.

In the sharp-nosed crab, *Scyra acutifrons* (*Fig.* 3) the testis is found to resemble that of the decorative crabs *Hyas lyratus* and *Oregonia gracilis* (Compare *Fig.* 3, *t.* with *Figs.* 3 and 4, *t*, page 39 of Fasten, 1915). The vasa deferentia of *Scyra acutifrons* (*Fig.* 3, *v.* d.), however, do not possess the diverticula found in the vasa deferentia of *Hyas lyratus* or *Oregonia gracilis* (See *Figs.* 3 and 4, *v.* d., page 39 of Fasten, 1915). In the black-clawed crab, *Lophopanopeus bellus* (*Fig.* 4), the portions of the male reproductive organs are built according to the plan outlined. However, the vasa deferentia (*Fig.* 4, *v.* d.), are profusely coiled just below the region where they leave the testicular lobes.

3.   MALE REPRODUCTIVE ORGANS OF ANOMURA

The male reproductive organs of the Anomura, in both sexes, differ

in their location from those of the Brachyura, being situated in the abdomen. This is true alike of the hermit as well as of the free-living Anomura. The latter, however, show some interesting modifications.

Let us first consider the male reproductive organs in *Lopholithodes mandtii, Haplogaster mortensii* and *Rhinolithodes wossnessenskii.* All these Anomura belong to the family Lithodidae of the tribe Paguridea and this tribe also includes the true hermit crabs, which comprise the family Paguridae. Calman (1909), in speaking of the testes of the Paguridae, says: "In the Paguridae they are displaced backwards so as to lie wholly in the abdominal region, where they are unsymmetrically placed on the left side, either fused into a single mass or entirely separated from each other, the right testis lying in front of the left." In many respects the testes of the Lithodidae under consideration resemble those of the Paguridae.

In *Lopholithodes mandtii (Fig. 5)* there is a pair of testes (*Fig. 5, r. t.* and *l. t.*) located slightly above the middle of the abdominal cavity well towards the left side. The left testis (*Fig. 5, l. t.*) lies lower down in the abdominal cavity than the right one (*Fig. 5, r. t.*). From each testis a stout vas deferent tube (*Fig 5, r. v. d.* and *l. v. d.*) makes its way upward to the hidden fifth thoracic leg on its respective side (*Fig. 5, f. l.*), and after traversing both the coxopodite and the basipodite, it then opens to the exterior through a small pore (*Fig. 5, r. o.* and *l. o.*). A closer examination of each testis shows that it is profusely tubular, seeming to be composed of a single slender tube which has become greatly convoluted and massed. Each testis is distinct and possesses a main lower portion with a thin upwardly projecting part (See *Fig. 5, r. t.* and *l. t.*), which runs along the outer wall of its vas deferens.

The male reproductive organs of *Haplogaster mortensii* and *Rhinolithodes wossnessenskii* resemble each other very closely. Here, while the parts of these organs show the same asymmetry as the abdomen, yet there is more symmetry displayed in the internal arrangement of their various portions than in *Lopholithodes mandtii* or in the Paguridae. The description for *Haplogaster mortensii* will also suffice for *Rhinolithodes wossnessenskii.* In *Haplogaster mortensii* there is a pair of tubular testes (*Fig. 7, r. t.* and *l. t.*) each of which is V-shaped and located on opposite sides of the intestine (*Fig. 7, int.*) in the middle of the abdominal region. From each testis a vas deferens (*Fig. 7, r. v. d.* and *l. v. d*) makes its way upward to the base of the degenerate fifth leg (*Fig. 7, f. l.*) on its respective side, where it opens to the outside.

Petrolisthes eriomerus is an Anomuran belonging to the tribe Galatheidae. This tribe is distinguished from the Paguridea by having its parts

symmetrically arranged. Located within the abdomen of *Petrolisthes eri-
omerus* (*Fig.* 8), the male reproductive organs are found lying symmet-
rically on either side of the intestine (*Fig.* 8, *int.*). Each testis (*Fig.* 8,
r. t. and *l. t.*) is a tubular mass from which is given off a long, thin, pro-
fusely coiling tube, the vas deferens (*Fig.* 8, *r. v. d.* and *l. v. d.*) which
runs to the base of the fifth thoracic leg (*Fig.* 8, *f. l.*) on the same side,
where it opens to the outside.

4.   HISTOLOGY OF THE VASA DEFERENTIA OF DECAPODA

One who is familiar with the male reproductive elements of the De-
capoda knows that the mature spermatozoa as they are removed from the
vasa deferentia are usually found in pouches known as spermatophores,
and that these spermatophores are suspended in a thick whitish fluid which
is viscid in consistency. Now the question arises, how are these parts
produced? Dahlgren and Kepner (1908) in discussing the nidamental tis-
sues of crutacea have the following to say concerning these structures:
"Another form of male-carrying fluid is secreted by the spermatophoral
glands of certain crutaceans, as the lobster and the crayfish. This fluid
is secreted by the walls of the sperm ducts, and it not only serves as a
vehicle to carry the mass of sperm out of the male organs, but it also
forms a semifluid covering around them and attaches itself to a receiving
plate on the female body and hardens, preserving the life of the sperma-
tozoa for months or even years until they are needed to fertilize the eggs."
A histological study of the vas deferent ducts of the numerous Decapoda
already mentioned in the introductory remarks has revealed the fact that
in all these forms this sperm carrying fluid and the spermatophores are
elaborated by an internal layer of epithelium, which is more or less gland-
ular in nature. In some of these Decapoda this epithelial layer assumes
interesting modifications, and the cells may also bear cilia.

A.   *The Vasa Deferentia of Anomura*

The Anomura studied were *Lopholithodes mandtii* and *Pagurus seto-
sus.* The vas deferens of *Lopholithodes mandtii* consists of five layers. (1)
a thin outer serosa of epithelium and (2) underneath this is a subserosa
of fibrous connective tissue. In most of the sections examined these first
two layers are sloughed off, due to the poor preservation of the material
from which the sections were made. Then follow two layers of smooth
muscle, one of which (3) is a circular layer (*Fig.* 11, *c.*) and the other
(4) a longitudinal one (*Fig.* 11, *d.*). Following these there is (5) a thin
inner layer of cuboidal epithelium (*Fig.* 11, *e*), which appears to be uni-
form throughout the tube. This inner epithelium secretes a thick fluid
which hardens into numerous wide, firm, convoluted membranes (*Figs.* 9-11,

f) from which are suspended the spermatophores (*Figs.* 9-11, *g*) filled with the mature spermatozoa. These spermatophores are formed from the same secretion as the membranes, and many of them are usually found in a row attached to the membrane wall (See *Figs.* 9 and 10, *g*).

When a portion of the vas deferens of *Lopholithodes mandtii* is cleared and examined in its entirety (*Fig.* 6). it appears as if the interior consists of numerous tubes (*Fig.* 6, *f*) which are enclosed in a large outer investing tube (*Fig.* 6, *g*). A study of longitudinal (*Fig.* 10) and cross-sections (*Fig.* 9), however, reveals the true nature of these structures. The investing tube (*Figs.* 6, 9 and 10, *j*) is then recognized as the vas deferent tube proper, while what appears to be the numerous internal tubes (*Figs.* 6, 9, 10 and 11, *f*) are not tubes at all, but are convoluted membranes with suspended spermatophores, the structures formed from the secretions of the lining epithelium.

In *Pagurus setosus* (*Figs.* 12-16), one of the true hermit crabs, the vas deferens is made up of the same structures as the vas deferens of *Lopholithodes mandtii*. Owing to the better preservation of the material from *Pagurus setosus*, the five layers (*Figs.* 14-16, *a, b, c, d, e*) are seen more distinctly, especially the first two layers, namely, the serosa (*Figs.* 14-16, *a*) and the suberosa (*Figs.* 14-16, *b*). In *Pagurus setosus* the interior epithelium becomes somewhat modified. Here, throughout most of the vas deferent tube the epithelium is thin and uniform, and consists of a single layer of ciliated cuboidal cells (See *Fig.* 16, *e*). However, at one point of the tube the epithelial cells become concentrated into a mass of elongated columnar cells bearing prominent nuclei and also possessing very fine examples of cilia from their free borders (See *Figs.* 14, 15, 28, 29, *e* and *h*). In Figs. 28 and 29, which are microphotographs of cross sections of some of the epithelial cells in this region taken under a high magnification, the cilia are seen very prominently. In Fig. 28 many of these cilia are found clinging together into "brushes." In Fig. 29 the individual cilia are especially well seen. These cilia arise from a distinct border; they possess basal granules, and in many instances they may be followed down into the cytoplasm of the cells.

This concentrated region of epithelium appears to be the place where most of the internal secretion is elaborated. This secretion is also laid down somewhat differently than in *Lopholithodes mandtii*. In *Pagurus setosus* the elaborated membranes are not nearly as convoluted, being deposited in layers which harden into more or less straight sheaths (*Figs.* 12-14, *f*). The spermatophores (*Figs.* 12-14, *g*) may be observed tightly wedged into the spaces between these sheath-like membranes.

B.   *The Vasa Deferentia of Brachyura*

The Brachyura studied were *Cancer magister, Cancer oregonensis* and *Lophopanopeus bellus.* In these Brachyura the vas deferens is constructed on virtually the same plan. There are three coats, (1) an outer thin layer of fibrous connective tissue (*Figs.* 17-20, *b*), and (2) immediately under this there is a thin circular layer of smooth muscle (*Figs.* 17-20, *c*), while (3) the interior consists of a prominent layer of columnar epithelial cells (*Figs.* 17-20, *e*), which contain huge nuclei. There is usually a difference in the epithelium of the proximal and distal ends of the duct.

In the edible crab, *Cancer magister*, the proximal end of the vas deferens (*Fig.* 19) contains a very well developed layer of epithelium which is convoluted (*Fig.* 19, *c*). The cells are greatly elongated, possessing basal nuclei and numerous vacuoles distributed through the cytoplasm (See *Fig.* 19). A careful examination of these cells shows that the vacuoles originate immediately below the nuclei, and that they then migrate past them to the distal ends of the cells where they are dischargd into the lumen of the vas deferens. In all probability these vacuoles are filled with the secretion that helps to carry the spermatozoa down through the duct and also functions in the formation of the spermatophores. The free surface of these epithelial cells is thickened into a distinct cuticula (*Fig.* 19, *k*), which under the high powers of the microscope is seen to contain numerous short, stiff, vertical rods. Immediately below this cuticular border terminal bars can be distinctly discerned.

In *Cancer oregonensis* a similar condition to that just described prevails in the proximal end of the vas deferens. In *Lophopanopeus bellus* the epithelium in the proximal end of the vas deferens (*Fig.* 17, *e*) is not convoluted but resembles that found in the distal end of the duct (*Fig.* 18, *e*). Furthermore the lumen in the proximal end of the tube is very much wider than in either *Cancer magister* or *Cancer oregonensis* (Compare *Figs.* 17 and 19), and it also contains many mature spermatozoa (*Fig.* 17, *s*).

The distal ends of all the crabs studied show the same general structure. The tube itself as well as its lumen is very much larger in this region (Compare *Figs.* 17 and 19 with *Figs.* 18 and 20). The epithelial cells, however, except in *Lophopanopeus bellus,* are comparatively smaller (Compare *Figs.* 19 and 20, *e*). In *Lophopanopeus bellus* the epithelial cells of the distal and proximal ends are similar in appearance (See *Figs.* 17-18, *e*). Within the lumen of the distal ends of these tubes of *Cancer magister* and *Cancer oregonensis* numerous spermatophores (*Fig.* 20, *g*) are seen suspended within the fluid secretions. In *Lophopanopeus*

bellus (*Fig.* 18) it doesn't seem as if numerous spermatophores are developed. Here it appears that one large spermatophore is formed (*Fig.* 18, *g*) in which the spermatozoa are tightly packed.

The observations on the above Brachyura are in many ways similar to those of Binford (1913), on the vas deferens and spermatophores of the crab *Menippe mercenaria.* In discussing the vas deferent duct, on page 149, Binford (1913) says: "The deferent duct is lined with a layer of columnar epithelium which secretes the substance that forms the walls of the spermatophores." In speaking of the spermatozoa in the vas deferent duct this same author, on page 159 states, "The mature spermatozoa pass from the tubules of the testis into the deferent duct. The latter is a long, extensively folded tube lined with glandular epithelium. The spermatozoa form a common mass when they enter this tube, but the secretion formed by its lining flows in among them and separates them into groups. The secretion surrounding each group then hardens and so forms a membrane, so that finally there are an immense number of capsules containing the spermatozoa. These capsules are known as spermatophores. In this condition the spermatozoa are transferred to the seminal receptacle of the female crab."

C. *The Vasa Deferentia of Macrura*

The Macrura studied were *Astacus leniusculus, Homarus americanus* and *Panulirus interruptus.* The vas deferent tubes of all these forms agree in their general histological structure. There is (1) an outer fibrous connective tissue coat (*Figs.* 21, 23-25, *b*), (2) a circular layer of smooth muscle (*Figs.* 21, 23-25, *c*), and (3) an inner layer of columnar epithelium (*Figs.* 21, 23-25, *e*) which contains cilia.

In *Astacus leniusculus* the epithelial cells (*Fig.* 25, *e*) are more or less uniform and some of them have been found to possess short cilia on their free borders (See *Figs.* 26 and 27, *h*). The nuclei of the epithelial cells are very prominent, as can be seen by studying Fig. 25. The large nuclei indicate that ths cells manufacture a great deal of secretion. These secretions may be observed in various parts of the epithelial cells as vacuoles or bubbles. They are especially evident on the surface of the cells (See *Fig.* 25, *e*), and in the lumen of the vas deferens where they form a dense viscid fluid (*Fig.* 25, *f*), that surrounds the spermatozoa (*Fig.* 25, *c*). These heavy secretions in *Astacus leniusculus* appear to be of distinct advantage to the species, for when the spermatozoa are passed to the outside, the surrounding secretions harden into firm, white, tube-like structures which adhere very tightly to the ventral surface of the female's thorax, thereby preserving the life of the male germ cells until they are needed for fertilization.

In the Atlantic coast lobster, *Homarus americanus,* the proximal and distal ends of the vas deferens differ both in size and general arrangement of the inner epithelium.   The proximal end of the tube *(Fig.* 21) shows a more or less uniform layer of columnar epithelial cells *(Fig.* 21, *e).*   In one part of the duct these cells are slightly larger than in other regions (See *Fig.* 21) and, also, some of them appear to bear short cilia.   In the center of the tube the spermatozoa *(Fig.* 21, *s)* may be seen surrounded by the heavy, uniform fluid secretion *(Fig.* 21, *f)* manufactured by the epithelial cells.

The distal end of the vas deferens *(Fig.* 22) is very much larger in size, and its lining epithelium bears fine types of cilia *(Figs.* 33-34, *h).* Furthermore, this epithelium becomes highly convoluted in a number of places *(Fig.* 23, *e),* thus affording a very much larger surface for the manufacture of the milk-white secretions which also form the spermatophore pouches *(Fig.* 22, *g)* around the spermatozoa.   In the spaces between the inwardly projecting epithelium of the convolutions a tunica propria *(Fig.* 23, *p)* may be seen.

A careful study of the cells comprising the convoluted portions of epithelium in the vas deferens of *Homarus americanus* shows that these cells *(Fig.* 34) are very much longer than those forming the other uniform parts of the epithelium *(Fig.* 33).   Furthermore, the cilia borne by the former cells *(Fig.* 34, *h)* are much longer and coarser than those arising from the latter cells *(Fig.* 33, *h).*   Herrick (1909), who has studied the male reproductive organs of the lobster, makes no mention of cilia in the epithelium lining the vas deferens.   In good preparations these cilia can be distinctly seen projecting from the free borders of the epithelial cells, as may be observed from the microphotographs *(Figs.* 33 and 34, *h).*

In the spiny lobster, *Panulirus interruptus,* the vas deferens is very long and contains a uniform inner layer of ciliated columnar epithelium *(Figs.* 24 and 30, *e).*   At one point in the tube this epithelial lining dips inward *(Fig.* 24, *i)* and becomes profusely convoluted into a mass of simple tubular glands.   Here, as in *Homarus americanus,* there is also a tunica propria *(Fig.* 24, *p)* in the spaces between the convoluted epithelium.

When the vas deferent tube of *Panulirus interruptus* is studied in its entirety this convoluted glandular portion *(Fig.* 24, *i)* resembles a "typhlosole-like" structure.   Between it and the uniform layer of epithelium one finds a heavy milky fluid secretion, in the midst of which lies a white wavy and very much contorted membranous tube that contains the spermatozoa. The contortions of this last mentioned tube appear in cross-sections as open spaces *(Fig.* 24, *g),* and surrounding them may be seen the heavy secretion *(Fig.* 24, *f).*   When this secretion first comes out of the vas

deferens it is milky-white and viscid in consistency. However, in a short
while it changes to a firm blackish mass. This is in accord with the ob-
servations of Allen (1916), who describes reproduction in *Panulirus inter-
ruptus* in the following words: "Insemination takes place from a putty-
like mass of sperm material placed upon the ventral surface of the female's
thorax between the last three pairs of appendages. This mass contains
contorted tubular cavities in which the spermatozoa lie. It is at first
white and soft but in a short time turns black and becomes hard. It comes
to resemble whalebone in consistency."

In the epithelium of *Panulirus interruptus,* especially in that of the
typhlosole-like area (*Fig.* 24, *i*), the finest examples of cilia were ob-
served. In this last named region the cilia are very long and extend from
the outer surfaces of the cells as well as line the tubules of the glands
(*Figs.* 30 and 31, *h*). In cases in which these tubules have been cut
across (*Fig.* 32), the tubular cavity can be seen completely surrounded by
epithelial cells (*Fig.* 32, *e*), with their long cilia (*Fig.* 32, *h*) extending
freely into the lumen.

5. DISCUSSION

A comparative study of the vasa deferentia of the Decapoda reveals
the fact that they are all built on virtually the same plan. There are
three more or less well defined regions: (1) an outer protective region,
(2) a middle muscular region, and (3) an inner epithelial region. The
functions of these will be taken up in logical sequence.

(1) The outer protective region of the vas deferens serves the pur-
pose of protection. In the Brachyura and the Macrura it consists of a
single coat of fibrous connective tissue (*Figs.* 17-21 and 23-25, *b*), while
in the Anomura it is made up of two well defined layers, an outer thin
serosa of epithelium (*Figs.* 14-16, *a*) and below this is a thicker subserosa
of fibrous connective tissue (*Figs.* 14-16, *b*).

(2) The middle muscular region undoubtedly functions in the pas-
sage of the spermatophores and the viscid secretions from the interior of
the vas deferens to the exterior. In the Brachyura and the Macrura this
region is rather thin and consists of a single circular layer of smooth
muscle (*Figs.* 17-21 and 23-25, *c*). In the Anomura there are two layers
of smooth muscle, namely, an outer circular layer (*Figs.* 11 and 14-16, *c*)
and an inner longitudinal layer (*Figs.* 11 and 14-16, *d*). In all probabil-
ity the muscular region sets up peristaltic waves along the vas deferens,
which force the inner contents of the tube to migrate to the terminal
opening where they are expelled to the outside. In the Anomura, since
there are two well developed muscular coats, peristalsis must be much
more marked than in either the Brachyura or the Macrura.

(3)   In the Decapoda studied the inner layer of epithelium consists either of columnar or cuboidal cells.   It is glandular in nature and manufactures the heavy fluid secretions as well as the spermatophore cases (*Figs.* 9-14, 18, 20-22, 24 and 25, *f* and *g*).   Furthermore, in four species of Decapoda, namely *Pagurus setosus, Astacus leniusculus, Homarus americanus* and *Panulirus interruptus,* the cells of this inner epithelium possess cilia (See *Figs.* 26-34, *h*).

That cilia are universally absent in the Arthropoda is an assertion which is commonly met with in many of our leading zoological treatises. In another paper (Fasten, 1917) the author has given a few quotations concerning this question from some of the leading text-books on zoology, and these might well be repeated here.   Adam Sedgwick (1909), in his Student's Text-Book on Zoology, Vol. III, pages 316-317, in discussing the female reproductive organs of *Peripatus,* says: "These ducts in the female retain a ciliated lining (Gaffron), the only known instance of the occurrence of a ciliated tract among the Arthropoda."   Parker and Haswell (1910), in their Text-Book of Zoology, Vol. I (Revised Edition), page 526, state: "Arthropods are also characterized by the almost universal absence of cilia."   Kingsley (1912), on page 357 of his revised edition of Hertwig's Manual of Zoology, makes the following assertion concerning cilia in the Arthropoda: "The entire absence of cilia is noteworthy.   Ciliated cells have never been found in arthropods."   A similar remark is found in the fifth, revised edition of J. Arthur Thomson's (1913) Outlines of Zoology.   Thomson, in speaking of the characteristics of the Arthropoda, on page 281 says: "Ciliated epithelium is almost always absent."

That the above statements are mere assumptions becomes apparent when the data presented in this paper are examined.   As already mentioned, the writer has found splendid examples of ciliated epithelium in four species of Decapoda (*Figs.* 26-34, *h*).   Furthermore, Gaffron (1885) has found ciliated epithelium in ducts of the female reproductive organs of neotropical species of *Peripatus.*   Also, Vignon (1901) observed a single case of ciliated epithelium in the digestive apparatus of a *Chyronomus* larva.   In the light of these observations it would not be amiss to predict that further investigation in the Arthropoda will in all probability show that cilia are more generally present among the members of this phylum than has hitherto been assumed.

6.   CONCLUDING REMARKS

In connection with the foregoing studies on the Decapoda, numerous questions have arisen upon which data is lacking.   First of all, accurate information is needed concerning the spawning habits of the Decapoda, especially such forms like the lobster, shrimp and crab.   Herrick (1909),

discussing this topic, says: "The behavior of the American lobster at the time of pairing and extrusion of the eggs has probably never been witnessed in a state of nature, and certainly but seldom in any of the higher crustacea." On our Pacific coast more investigation on the breeding habits of the shrimp and the edible crab would be very desirable, particularly from an economic standpoint.

Secondly, the longevity of the spermatozoa is another topic of vital importance in conjunction with the Decapoda. Most investigators working on the Decapoda agree that the spermatozoa can remain dormant for long periods of time, but no accurate information is available concerning the length of time or the conditions necessary to preserve the life of these male germ cells.

Thirdly, more knowledge is needed concerning fertilization in the Decapoda. The investigations on this topic have been so few and opinions have differed so widely that there is room for more extensive research along this line.

This entire discussion might well be concluded with the following significant remarks from Herrick (1909). In speaking of the pairing of higher crutacea Herricks says: "There are three subjects. apart from the more special problems of cytology, concerning which exact knowledge is particularly needed. These are: (1) The exact role played by the cement-producing organ: (2) the kind of stimulus or stimuli needed to arouse the sleeping sperm in its receptable, set it in motion, and direct its course to the eggs; and (3) more light on the action of the rays, and the "explosive capsule," by means of which recent students have endeavored to explain the forced entrance of the head of the sperm into the egg. Direct observations are too limited at present to afford a basis for the final settlement of any of these matters."

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8. DESCRIPTION OF PLATES

The figures on plates 1 and 2 are drawings from dissections. Those on plates 3-5 are microphtographs from sections taken by the author. None of the photographs were retouched in any manner whatsoever.

ABBREVIATIONS

a=thin outer coat of epithelium.

b=layer of fibrous connective tissue.

c=circular layer of smooth muscle.

d=longitudinal layer of smooth muscle.

e=inner layer of glandular epithelium.

f=interior secretion of vas deferens.

f. l.=fifth pair of legs.

g=spermatophores.

h=cilia.

i=convoluted, "typhlosole-like" portion of inner epithelium.

int=intestine.

j=outer investing coats of vas deferens.

k=cuticula.

l. o.=opening of vas deferens on left side.

l. t.=testis of left side.

l. v. d.=vas deferens of left side.

p=tunica propria.

r. o.=opening of vas deferens on right side

r. t.=testis of right side.

r. v. d.=vas deferens of right side.

s=spermatozoa.

t=testis.

v. d.=vas deferens.

x=union of two lobes of testis.

PLATE 68

Fig. 1. *Cancer gracilis.* $\times$ 0.9.

Fig. 2. *Cancer oregonensis.* $\times$ 0.9.

Fig. 3. *Scyra acutifrons.* $\times$ 0.9.

Fig. 4. *Lophopanopeus bellus.* $\times$ 0.9.
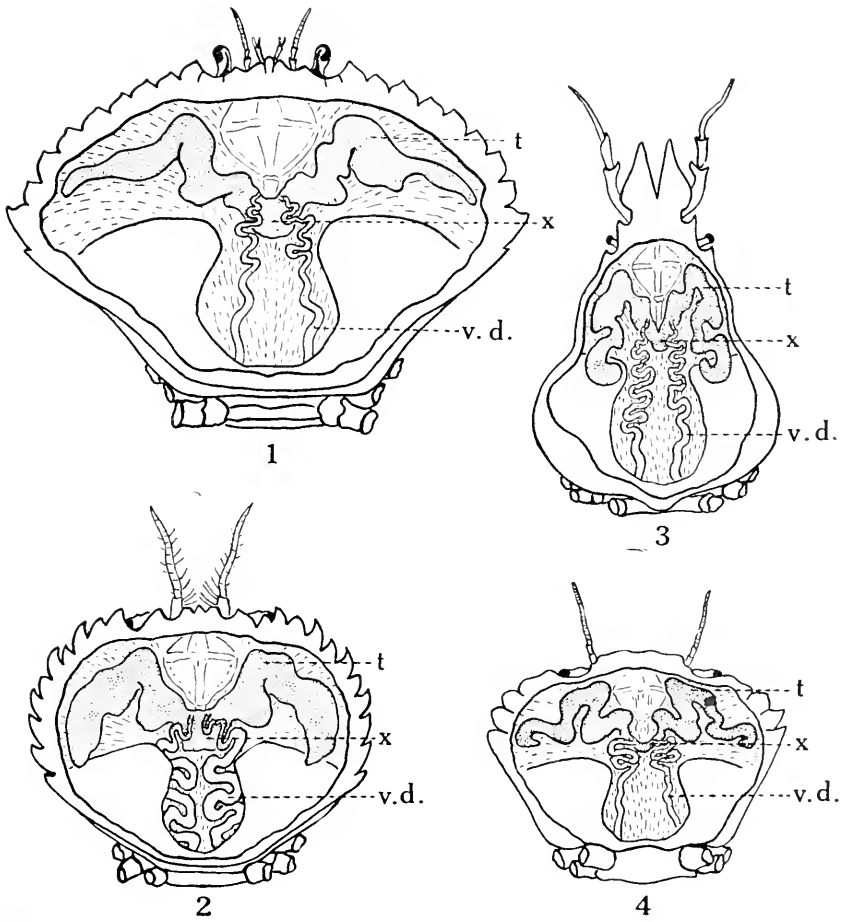
N. *Fasten, Del.*   PLATE 68

PLATE 69

Fig. 5.   Abdominal region of *Lopholithodes mandtii,* male, showing parts of reproductive organs. $\times$ 0.75.

Fig. 6.   Portion of vas deferens of *Lopholithodes mandtii,* showing structure.   The inner, convoluted, membranous secretions (f) are surrounded by an investing tube (j) which is the wall of the vas deferens proper. $\times$ 10.

Fig. 7.   Abdominal region of *Haplogaster mortensii,* male, showing parts of reproductive organs. $\times$ 1.75.

Fig. 8.   Abdominal region of *Petrolisthes eriomerus,* male, showing parts of reproductive organs. $\times$ 3.5.

5

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6

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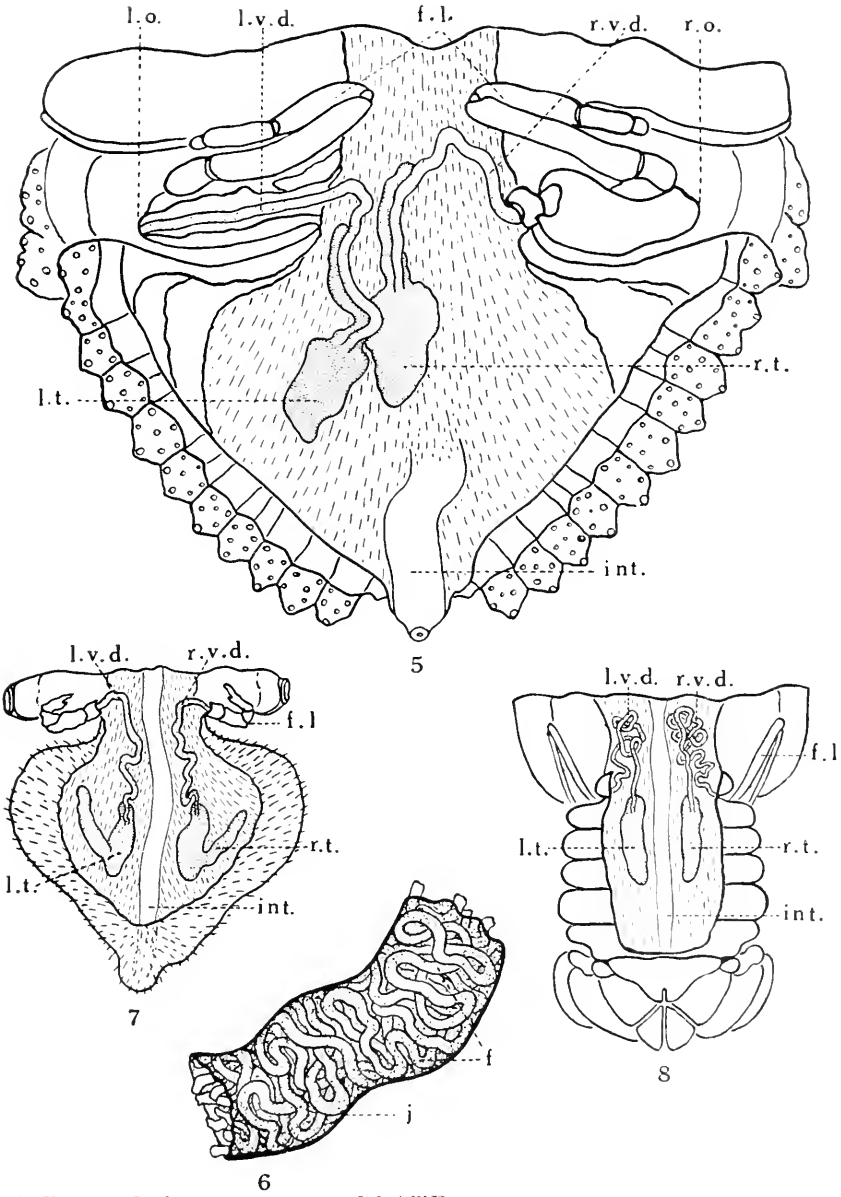
PLATE 70

Microphotographs

Fig. 9.   Cross section of vas deferens of *Lopholithodes mandtii*, showing outer coats (j), and inner convoluted membranes (f) with suspended spermatophores (g).   × 18.

Fig. 10.   Longitudinal section of vas deferens of *Lopholithodes mandtii* showing arrangement of parts.   × 18.

Fig. 11.   Portion of cross-section of vas deferens of *Lopholithodes mandtii* showing structure in greater detail.   The first two coats, the serosa (a) and the sub-serosa (b), are missing in the section.   × 113.

Fig. 12.   Cross section of vas deferens of *Pagurus setosus* showing outer coats (j) and inner membranous sheaths (f) with spermatophores (g).   × 18.

Fig. 13.   Longitudinal section of vas deferens of *Pagurus setosus* showing arrangement of parts.   × 18.

Fig. 14.   Portion of cross-section of vas deferens of *Pagurus setosus* in region of concentrated columnar epithelium.   × 113.

Fig. 15.   Enlarged portion of cross section of vas deferens of *Pagurus setosus* in region of concentrated epithelium to show the arrangement of the five layers (a, b, c, d, e).   Cilia (h) can also be seen.   × 280.

Fig. 16.   Enlarged portion of cross-section of vas deferens of *Pagurus setosus* in region of cuboidal epithelium to show the five layers (a, b, c, d, e).   × 320.

Fig. 17.   Cross-section of vas deferens of *Lophopanopeus bellus*, proximal end.   × 52.

Fig. 18.   Cross section of vas deferens of *Lophopanopeus bellus*, distal end.   × 52.
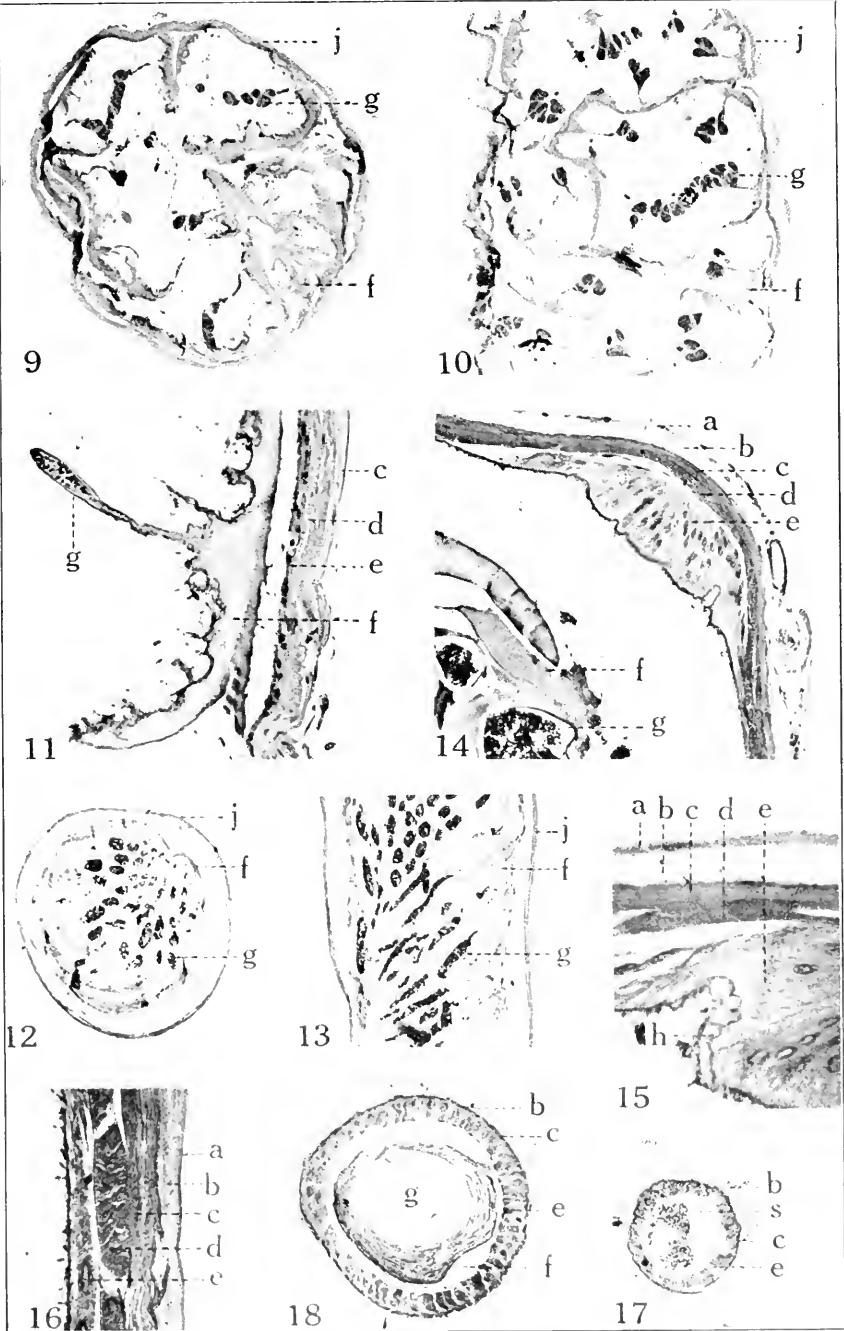
PLATE 71

Microphotographs

Fig. 19.   Cross-section of vas deferens of *Cancer magister*, proximal end.   × 52.

Fig. 20.   Cross-section of vas deferens of *Cancer magister*, distal end.   × 52.

Fig. 21.   Cross-section of vas deferens of *Homarus americanus*, proximal end.   × 52.

Fig. 22.   Cross-section of vas deferens of *Homarus americanus*, distal end.   × 18.

Fig. 23.   Portion of cross-section of vas deferens of *Homarus americanus*, distal end. to show details of structure.   Note the tunica propria (p) of convoluted portions of epithelium (e).   × 52.

Fig. 24.   Cross-section of vas deferens of *Panulirus interruptus*.   × 21.

Fig. 25.   Cross-section of vas deferens of *Astacus leniusculus*.   × 52.

Figs. 26-27.   Enlarged portions of epithelium of vas deferens of *Astacus leniusculus* to show the cilia (h).   × 510.
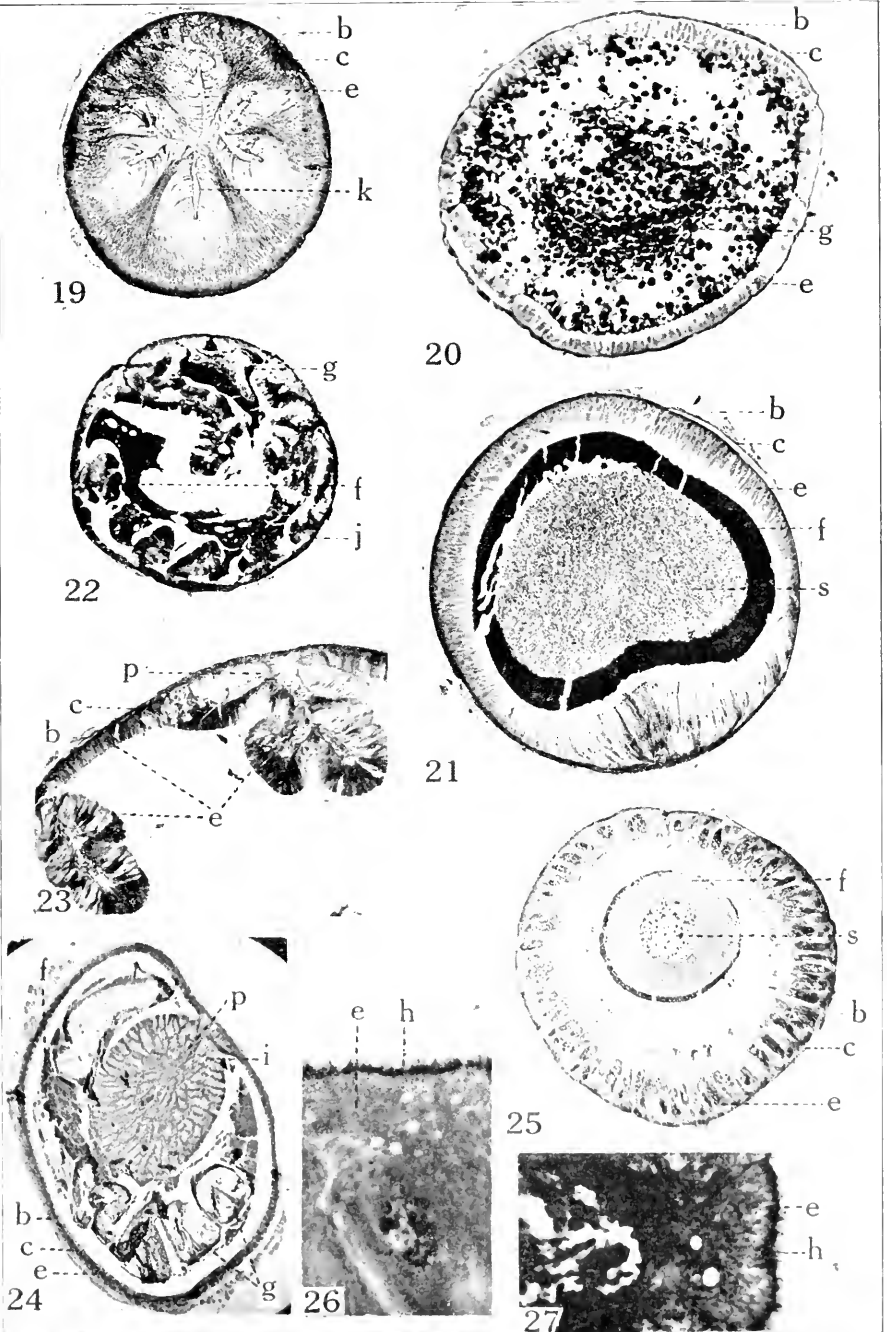
PLATE 72

Microphotographs

Figs. 28-29.   Enlarged portions of columnar epithelium of vas deferens of *Pagurus setosus* to show the cilia (h).   × 510.

Figs. 30-31.   Enlarged portions of glandular epithelium from typhlosole-like region of vas deferens of *Panulirus interruptus* to show the cilia (h).   In Fig. 31 the cilia (h) line the lumen of the tubule.   × 510.

Fig. 32.   Cross section of a tubule of *Panulirus interruptus* similar to that seen in Fig. 31, showing the lumen completely enclosed by epithelial cells (e) which bear long, freely extending cilia (h).   × 510.

Fig. 33.   Cells from uniform portion of epithelium in distal end of vas deferens of *Homarus americanus* showing the cilia (h).   × 510.

Fig. 34.   Cells from convoluted portion of epithelium in distal end of vas deferens of *Homarus americanus* showing the coarse cilia (h).   × 510.
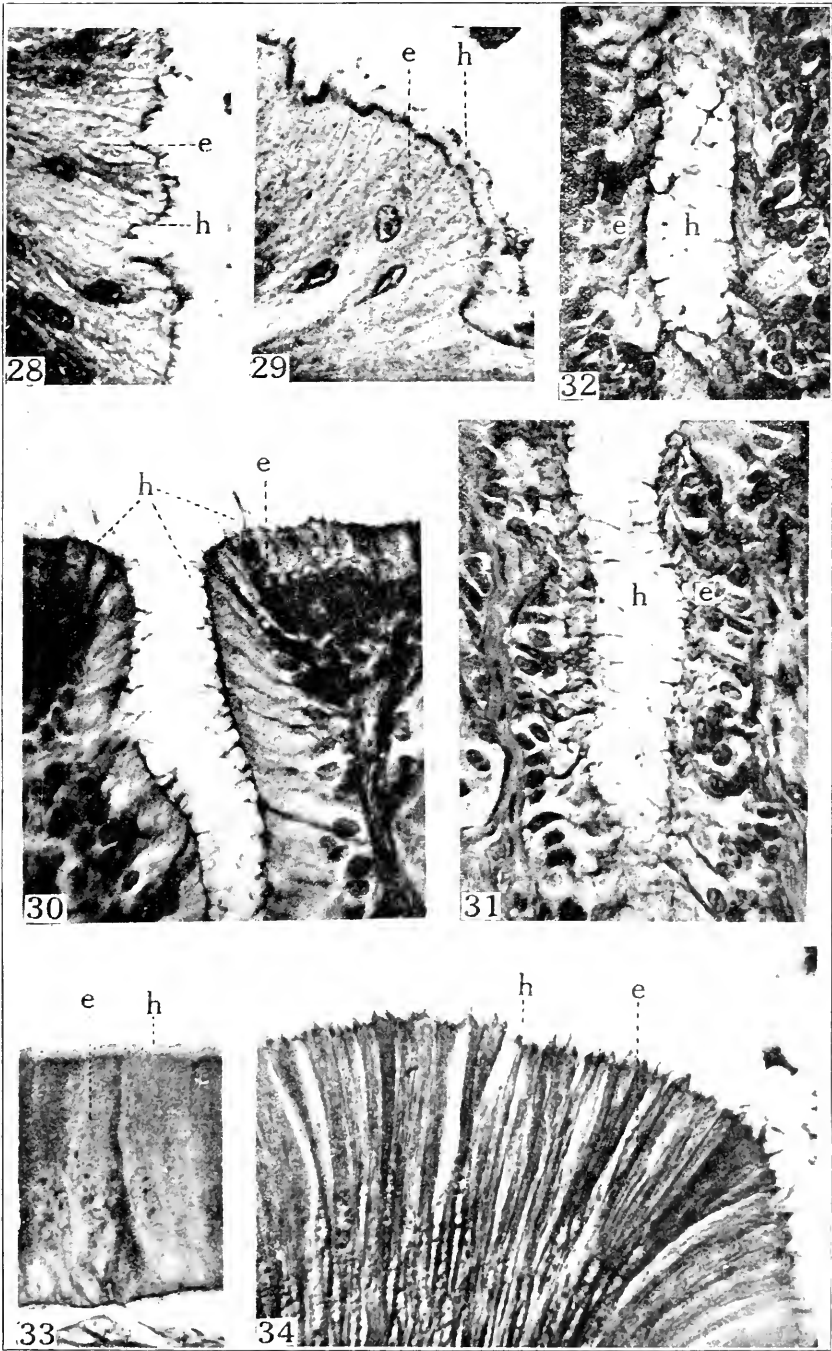
Seasonal Development of Bladder Kelp

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I. INTRODUCTION

Since exact data as to the state of development of this kelp
(*Nereocystis luetkeana*[1]) in some one bed at different seasons seemed
desirable, the writer began in the fall of 1914 to make observations on
the kelp bed at Lincoln beach near the southern boundary of the City of
Seattle. Data on the stage of growth of this plant at different seasons,
together with discussions in interpretation of the data, have been con-
tributed by Frye,[2][3] Setchell,[4][5] the writer[6][7][8] and others.

It is not considered necessary in this paper to discuss the structure
and development of this plant, since these facts are touched upon in the
papers just cited and are more fully considered in a paper by MacMillan.[9]

The kelp bed on which these observations have been made has varied
a good deal in size at the different dates of observation, reaching its max-
imum size in late summer, but at its best development it has exceeded 700
feet in length and has shown an average width of more than 40 feet. The
height of the tide and the state of the water with regard to waves and
tidal currents are also important factors to consider in estimating the size
of the bed. Many specimens of this kelp, even in late summer, are too
short to reach the surface of the water except at extreme low tide. Many
of the plants that would otherwise be readily seen are rendered incon-
spicuous by movements of the water due to winds and tides. In extreme
cases these causes may render portions of the bed invisible except to an
observer in a boat directly over the kelp.

The following are the dates of observations on this bed, together with
the more important facts observed. Each visit except numbers 1, 5 and

[1] Whenever the word "kelp" is used in this paper, it refers to this species.
[2] Frye, T. C. Nereocystis luetkeana. Bot. Gaz. 12:113-146. 1906.
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1899.

8 included a trip over the bed in a rowboat. All observations reported were made by the writer except as otherwise noted.

2. FIELD OBSERVATIONS

1. *October,* 1914. Extreme high tide with no waves of consequence. Kelp plainly visible from the shore. The bulbs and fronds formed a dense mass at the surface. Length of bed estimated at 700 feet.

2. *April* 20, 1915. Low tide (+2.2 ft.). Water fairly quiet. Not a single kelp either old or young could be seen, although from the boat *Fucus* could be plainly seen in the water only a few feet further toward the shore than the edge of the bed as seen on visit No. 1.

3. *April* 30, 1915. Low tide (—0.1 ft). Water quiet. No plants of the previous season were found but plenty of young ones were seen. Eleven plants of representative sizes were measured. Their lengths were as follows: Maximum, 171 inches; minimum, 10 inches; average, 54 inches. Many kelps were entirely exposed at this state of the tide. There was an exposed zone about 15 feet wide in which kelps were abundant among *Laminaria, Gigartina* and other species of algae. This same algal association, including the kelps, extended below low tide and it was found that it was very difficult to see young kelps when they are under water and among other plants. A rise of two feet in the tide would cover the zone occupied by this association, hence it is probable that there were young kelps here on April 20, but that they escaped observation on account of the higher tide (a difference of 2.3 ft.) and the slight disturbance of the surface of the water by waves.

A careful search was made for "fruiting" specimens, i. e., plants that had begun to produce spores, but only one was found. The specimen was 114 inches long. It had one or two soral patches on nearly every frond. No soral patches had come out of any of the fronds and probably no spores had been discharged. Numerous small kelps 12 to 24 inches long were seen floating. As these specimens, even including the holdfasts, were intact, it was evident that their anchorage had failed.

4. *May* 29, 1915. Low tide (—1.1 ft.). Water fairly quiet. Measured 13 plants. Their lengths were as follows: Maximum, 25 feet; minimum, 3 feet; average, 11 feet. Although the tide was lower than during visit No. 3, no kelp plants could be found exposed. The zone above low tide in which numerous kelps were found a month before was gone over carefully but not a single kelp was found in it.

Of the 13 kelps measured, 7 were in some stage of spore production ("fruiting"). Of these seven, 4 showed only a very few soral patches, indicating that fruiting was just beginning in them. The remaining three

all showed numerous soral patches, but only one of these plants had lost any of its soral patches. The whole bed was examined and it is believed that the 13 plants reported were representative of the bed both as to size and state of spore production. Bed 250 feet long. No floating kelps seen.

In three of the specimens examined the stipe had grown in a corkscrew, or spiral form. All showed a roughened, slightly elevated line (⅜ to ¾ in. wide) correspondingly exactly with the spiral turns of the stipe. The spiral turns were very close together near the holdfast of the kelp and were gradually farther and farther apart toward the top of the stipe until at the bulb the line was practically straight. In every case the roughened line extended to one or more fronds.

5. *June* 6, 1915. Observations made from shore from 4:30 to 5:30 P. M. The tides during the afternoon were as follows: 12:50 P. M., +7.8 feet; 5:42 P. M., +6.6 feet. No kelp at all could be seen from the shore. Evidently the plants that were long enough to reach the surface at this stage of the tide were drawn under by it or were invisible on account of waves. One kelp 5 feet long was found drifted up on the beach. At another point about a dozen kelps of practically the same size were found entangled in a mass of brush drifted up on the beach.

6. *June* 27, 1915. Low tide (—1.1 ft.). Measured 11 kelps. Lengths were as follows: Maximum, 29 ft.; minimum, 5 ft.; average, 15 ft. No kelps could be found exposed. The inner edge of the bed was 15 to 30 feet from shore. Of the 11 kelps measured, 6, comprising all of those over 12 feet long, were fruiting. Of these six, five had discharged many of their soral patches. Only six floating kelps were seen during the 2½ hours spent at the bed. Three of these were 3 to 5 feet long and the others were 18 to 20 feet long. Soundings were made in the bed at the extreme low tide. The shallowest sounding, at the inside of the bed, was 2 feet. The deepest, at the outside, was 15 feet. The plants at the outer edge of the bed were practically all submerged. That is, they were not long enough to reach the surface even at this state of the tide. Extreme width of bed, 50 feet. Two "spiral" kelps were found.

7. *September* 9, 1915. Time, 2:30 to 4:00 P. M. High tide was 4:34 P. M., at Port Townsend, hence probably a little after 5 at this bed. The tidal current was running through the bed and very few kelps were visible. Evidently the crop of kelp was much lighter this year than in 1914. Measured three kelps. Their lengths were 26, 31 and 45 feet; average 34 feet. All kelps seen were fruiting abundantly. Many soral patches had come out, so that the ones seen still in the fronds were all near the base of the fronds.

Ten kelps were pulled up to examine their anchorage. One was attached to a single large stone (8 or 10 inches in diameter). Each of the others was attached to several small stones (1 to 4 inches in diameter).

8. *March* 25, 1916. Low tide (+1.4 ft.). Observations made from shore only. Could find no kelp at all either young or old.

9. *April* 22, 1916. Low tide (+0.3). Found only one old (1915 crop) kelp plant. Its fronds were all gone and, while it was still attached, its holdfast loosened by very slight pulling. Two young kelps were growing on the lower part of its stipe. One of these was 12 inches long and the other 7 inches. These were the only young plants found that could be positively identified as *Nereocystis,* although there were many young Laminariaceae less than three inches long growing on the rocks on shore near low tide. Some of these may have been *Nereocystis* but the close similarity among the several genera of this family during the early stages made it impossible to identify any of them positively.

10. *May* 20, 1916. Low tide (—0.8). Water very rough. Kelps were abundant both on shore and in the water. Measured 37 kelps. The longest was 11 feet and the shortest was 7 inches. The average length was 43 inches. A careful search was made for fruiting specimens but only three were found. The average length of the three was 10 feet. Two of them had already lost several soral patches near the ends of the fronds. There were numerous specimens of Laminariaceae growing above low tide whose genus it would be impossible to identify positively. Kelps were numerous at 1 foot (vertical distance) above low tide and a number were found even 3 feet above low tide. Effects of desiccation were plainly seen on some of these.

11. *June* 20, 1916. Low tide (+1.9 ft.) was at 3:05. We arrived at 3:50. Plenty of kelps were seen where the water was 2 feet or more deep but none could be found on shore or in the very shallow water. Seven kelps were measured. Their average length was 15 feet. The shortest was 13 feet and the longest 16 feet. All of these specimens but one were fruiting.

12. *July* 14, 1916. Low tide (—0.09 ft.). Found 11 kelps exposed at this stage of the tide. The shore along the whole edge of the bed was examined but no more could be found. The eleven specimens averaged 4 feet in length. The shortest was 1½ feet, and the longest 9½ feet. None of them was fruiting. But few fronds were present on any of them and the few that were present were badly beaten to pieces. All of these 11 kelps were attached to small stones.

The bed was over 700 feet long. Its width was from 20 to 65 feet. Three spiral kelps of the usual type were found.

Kelps were abundant in the water. Twelve specimens were measured. They averaged 13 feet in length. The longest was 24 feet. The shortest (2 feet) was growing on the stipe of another kelp. All of them that exceeded 8 feet in length were fruiting abundantly. Many kelps were too short to reach the surface of the water and it could be seen that many of them were not fruiting.

13. *Oct. 21, 1916.* Observations continued from 10:45 A. M. to 12:30 P. M. High tide (13.2 ft.) was at 1:37. The bed visible was approximately 600 feet long and 20 to 40 feet wide. Five kelps were measured. The longest was 48 feet and the shortest 30 feet. They averaged 35 feet. Four of these were fruiting abundantly. The fifth had ceased fruiting, all of the soral patches having fallen out. Twenty other kelps were examined and were all found to be fruiting abundantly. By looking at the fronds in the water as we passed over the bed in a boat, fruiting was found to be common throughout the bed. Five specimens, in all, were examined which showed the soral patches all gone so that fruiting had ceased. Only three specimens were found in which decay had begun in the stipe.

About a dozen specimens were seen floating. The attachment of a number of kelps was tested by pulling on them. Only 6 were found to give way with sufficient ease to indicate that their attachments was weakening. Of these, four showed shale still attached to their foldfasts, suggesting that it was the material to which they were attached that had given way, rather than the holdfast itself.

As a whole this kelp bed was still in good condition on this date. That is: (a) No serious decay has yet set in. (b) The kelps are still firmly attached. (c) Fruiting is still going on.

Some of the kelps had as much as 6 feet of the stipe lying on the surface of the water at this stage of the tide, while others, particularly at the outside of the bed in deeper water, did not come to the surface by 4 feet. There were all gradations between these two extremes. The tide was almost slack and many of the fronds were observed to be hanging directly downward.

14. *Dec. 11, 1916.* (The data of this observation were furnished by Miss Joanne Karrer.) Tide, about 9 feet. Water rough. A good many fronds still showed soral patches, and were apparently still discharging spores. Many kelps, however, were entirely without fronds. Decay was beginning in the stipes of many specimens. Some floating kelps were seen.

15. *Feb. 28, 1917.* Observation from 4:15 to 4:40 P. M. Low tide at 4:39 P. M. (+3.0 ft.) The kelp bed was 650 feet long, and from 15

to 30 feet wide. The inner edge of the bed was 20 to 50 feet off shore. There were some dense mats of kelps but in the main the bed was thin. Practically all of the beds were much overgrown with *Ulva, Ectocarpus* and *Antithamnion.* The bulbs and stipes were decayed in a few kelps, but in the main both were sound. There were only a few fronds on the kelps. Many had no fronds at all. When present, the number varied mostly from 1 to 5. There were few with more than 5. Such fronds as were still present on the plants showed soral patches at the base. The number of soral patches varied from 0 to 3. Places where 3 to 6 patches had dropped out were still visible.

16. *Miscellaneous data from places other than Lincoln Beach.*

On May 6, 1913, the writer found young kelp plants growing on the piling of the dock at Campbell River, B. C. The plants were from 3 to 5 feet long. The fronds still showed basal splitting and no soral patches were found on any of them.

On June 1, 1913, near Renard Island on Resurrection Bay, Alaska, a kelp bed was found containing mature kelps, practically all of them fruiting and one of them showing any signs of decay. Similar conditions had been observed at Naked Island in Prince William Sound on May 27 where the stipes of many of the plants were literally covered with young plants of *Alaria, Cymathere and Porphyra.* These two observations are representative of conditions observed in Alaska during the early part of the summer of 1913. It was frequently observed at various points that large masses of kelp were drifting loose during the early summer and that the beds thickened very noticeably with new kelps during the middle and later summer. During the observation of June 1, mentioned above, it was noticed that no tide was running through the bed, and that the masses of fronds hung straight down. The same fact was noted at Kodiak, Alaska, on July 5 and was observed at other places in Alaska during the summer.

On April 3, 1916, the writer saw young kelp plants about 18 inches long on piling at Pleasant Beach, Washington. On April 11, 1913, he examined several kelp plants collected by Mr. J. Fred Wright of Seattle, at Marrowstone Point, Washington. These plants were, in general, in good condition. They showed no decay and their fronds showed several soral patches, apparently still containing spores. One young *Nereocystis* plant 8 inches long was attached to the stipe of an old one. On April 25, 1915, during a trip from Seattle to Silverdale, numerous small kelps 1 to 2 feet long were seen floating in Agate Pass and also near the south end of Bainbridge Island.

On Feb. 26, 1915, Mr. George A. Schwabland found plenty of kelp

for harvesting along the northwest portion of Orcas Island and at numerous other points among the San Juan Islands. He also found kelp in the Smith Island bed, but the water was too rough to permit of accurate observations as to quantity or condition.

On Dec. 26, 1916, kelp was observed by the writer at Fort Ward, Pleasant Beach, and Waterman, all near Seattle. The observations were made from a steamer as it docked at these points. The tide was between 9 and 10 feet at the time of these observations, while the highest tide that day was 15.1 feet. A tidal current was moving past the kelps and they could be seen plainly. Some kelps were without fronds, but many still had them. It could not be determined from these observations whether any specimens were still fruiting. The beds were evidently much thinner than on the several occasions on which the writer had observed them during the summer. Considerable masses of drift kelp were lodged about the piling of the dock at Pleasant Beach and a considerable number of kelps were seen floating. Also on Mar. 16, 1917, at 6:30 P. M., at nearly low tide about 25 kelps were seen by the writer near the dock at Waterman. These were observed from the steamer as it docked. No fronds were seen, but there may have been a few short ones. There were many more than 25 kelps at this point earlier in the season. Again on Mar. 30, 1917, at 6:00 P. M. the writer saw a few old kelps mostly without fronds near the dock at Pleasant Beach at low tide. They were still attached.

Mr. George A. Schwabland of Victoria, British Columbia, told the writer that the openings made by the fishermen cutting away the kelp in order to keep free passage for their boats through the kelp beds among the Queen Charlotte Islands in very late summer are frequently filled in a short time with a new growth of kelp.

3. DISCUSSION

In the following discussion the writer makes use of the above data and also of the facts that he has noted during 9 years of observations along the shores of Puget Sound (three of which have been spent at the Puget Sound Marine Station) and one summer spent along the coast of western Alaska.

Nereocystis seems to be an annual plant. It seems to be the normal thing to find young plants in spring, fruiting specimens in summer, and to find the kelp either drifted loose or showing signs of old age during the following winter. Many individuals do undoubtedly live through the winter, but the larger number of them in the Puget Sound region disappear before they are a full 12 months old. The ones that survive are not always the ones in the most protected places. In Alaska it is certainly very

common for kelp to endure through the winter.[10] It seems to be a question of the ability of the plant to endure the rigorous environmental conditions. The general vigor and tone of the individual plant must, of course, be a large factor in this. The writer has seen no evidence that any specimens last through the second winter.

There does not seem to be any evidence of any resumption of growth with the coming of the second season that would warrant the use of either the term "biennial" or "perennial" with reference to these kelps. Their life activities seem to be comprised in one cycle, but this may be prolongd considerably by favorable environment. It is possible that internal factors may also contribute to the longer life of some individuals and the shorter life of others. How much of the duration of individuals of this species may be due to the potentialities of the plant itiself and how much to the influence of environmental conditions does not seem to have been determined.

The facts observed seem to be consistent with the idea that these kelps fruit during practically the entire year, but that, at least in the Puget Sound region, the fruiting is relatively so abundant during middle and late summer as to justify calling this the normal fruiting season. If any legal restriction is to be placed on the cutting of kelp in the interests of conservation, it would seem that a portion of each bed should be left uncut throughout the year rather than to limit all cutting to a definite season.

The mortality among young kelps is heavy. Many of the spores germinate on places where the plants cannot continue to thrive. The fact that many of them germinate on substrata which will not hold the plants[11] when buoyancy of bulb and straining because of water movements begin to test the quality of the attachment is evidenced by the large number of young kelps seen floating in early spring.

The data given for the bed at Lincoln Beach indicate that many spores germinate so far above low tide that the resulting kelps do not survive. The following causes may contribute to the death of these individuals: (a) Desiccation during exposure at low tide. (b) Exposure to strong light during this exposure. (c) Beating of the plants upon the rocks due to tidal and wind movements of the water. (d) Grinding of the young plants to death due to the shifting of small stones upon which they have found attachment.

Some evidence of the operation of (a) was seen during the summer of 1916 at Lincoln Beach. This season was about three weeks later, how-

10Frye, T. C. The kelp beds of souhteast Alaska. Rept. No. 100. U. S. Dept. Agric., p. 66, 1915.
11Cf. Frye, T. C. The kelp beds of southeast Alaska. Rept. No. 100. U. S. Dept. Agric., p. 66, 1917.

ever, than normal seasons of the region. The large number of cloudy and
rainy days undoubtedly saved many kelps from serious desiccation dur-
ing low tides. Muenscher[12] found that the average time that *Nereocystis*
plants could withstand desiccation on the beach at Friday Harbor, Wash-
ington, in bright sunshine without resulting in death was 1 to 2 hours. On
this basis either desiccation or light intensity must certainly be an im-
portant factor in the death of kelps above the line of low tide.

The observations at Lincoln Beach suggest that (c) is also a factor to
be carefully considered. If the kelps were being so roughly used as to
beat off nearly all of their fronds, death would certainly result from long
continuance of this treatment. The shingle on a gently-sloping beach is
shifted about a great deal by water movements, and it seems probable
that this may cause the grinding to death of many young kelps in the lit-
toral zone. It is possible that in the case of young plants attached
to small stones, water movements may result in the transportation of
plants and stones together to a higher position on the beach and thus in-
crease the danger from desiccation.

Since the fronds of this kelp hang directly downward in quiet water,
but are swept out horizontally very near the surface of the water in strong
tidal currents, it would seem that this may be an important factor in the
greater abundance and better development of the plants in the latter sit-
uation than in the former. Light for photosynthesis would, of course, be
more abundant in the second case than in the first due to both the changed
position of the fronds with reference to the light rays and also to the
smaller amount of water through which the light would pass in reaching
the fronds. Since the main source of carbon for food synthesis in these
plants must be the atmosphere, the second position of the fronds must be
the more advantageous for obtaining this carbon, whether the plant gets
its carbon directly from aqueous CO_2 or from bicarbonates.

It is evident, of course, that a complex of factors determines the loca-
tion of kelp beds. These have been discussed in the papers cited near the
beginning of this paper and by Miss Hurd.[13] Where kelp is lacking un-
doubtedly in many cases some one factor has become the limiting one, al-
though all of the others may be present. No doubt different factors be-
come the limiting ones in different cases. The difficulties of removing what
appears in any case to be the limiting factor in the distribution of the
plant are, of course, very great.

In the cases in which new kelps appeared at the surface of the water
following the cutting of portions of the beds in the Queen Charlotte Is-

[12]Muenscher, W. L. C. Ability of seaweeds to withstand dessication. Puget
Sound Marine Sta. Pub. 1:19-22. 1915.
[13]Hurd, Annie M. Factors influencing the growth and distribution of Nere-
ocystis luetkeana. Puget Sound Marine Sta. Pub. 1:185-197. 1917.

lands, it seems probable that the increased light available due to the removal of the dense mat of older kelps resulted in increasing the growth of young plants below, whose growth had formerly been inhibited by lack of light. In harvesting *Macrocystis,* a perennial kelp on the California coast, it has been reported that a new growth of kelp appears at the surface in the cut areas within a short time. This is explained as due to the "stooling cut" of the plants from the base.[14] The California cases and those in the Queen Charlotte Islands, while appearing superficially alike, are thus evidently due to very different causes.

No cause for the spiral form and the accompanying roughening of kelps seems evident. It is true, of course, that kelps growing in large clusters are commonly twisted together and many of these show a somewhat spiral form, but the spiral in these cases shows few turns and no roughening corresponding to the spiral. There does not seem to be any evidence that the roughened spirals observed are due to the kelps twining about any object. Mechanical injury and the presence of organisms seem to be likewise difficult to establish as causes.

The kelp bed that has been made the basis of this study is not a large one as compared with many others of the region. Neither do the individual kelps in it reach any more than average size. This bed was selected for study because its location made it possible for the writer to visit it conveniently at different seasons. It is fairly representative of average conditions. In general, larger beds and more vigorous kelps are found in the rougher waters that communicate more directly with the Strait of Juan de Fuca.

14Cameron, F. K. Pacific kelp beds as a source of potassium salts. Rept. No. 100. U. S. Dept. Agric., p. 15. 1915.

Early Development of the Chinook Salmon

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CONTENTS

INTRODUCTION AND MATERIALS

Scientific investigations upon the Pacific salmon as far as papers published on the subject would indicate, have been concerned with the natural history and behavior of the salmon and with the growth, development and care of the young fish. Most of the papers dealing with the question of teleost development are concerned with the embryology of pelagic eggs. Henneguy (22) and Klein (28) have investigated the embryology of the trout. Hertwig (21), Ryder (42) and Sumner (44) used Salmonoids as material for embryological study. So far as the writer is aware no work has been done upon the early development of the salmon of the Genus *Oncorynchus* of which the Chinook salmon (*O. tschawytscha*) is a species. For this reason this work was undertaken.* The observations recorded are mainly concerned with the external features of development.

The eggs were fixed in Bouins killing agent and preserved in 85% alcohol. Thus preserved, the yolk coagulated into a hyaline mass. Benda's iron haematoxylin was used in staining sections, and eosin and orange G were employed as counter stains. Satisfactory sections were obtained by this procedure. Whole eggs stained with Delafield's acid haematoxylin and mounted in balsam made good preparations. Owing to the large size of the egg, only the cap of the yolk upon which the disk or embryo rests was used in preparing slides.

The Chinook salmon (*Oncorynchus tschawytscha*) is found on the shores and in the streams along the Pacific Coast from Kamchatka to southern California. It spends most of its life in the ocean, returning to the rivers during certain seasons to spawn. The gonads are immature when the fish enters the river. Secondary sex characters appear during the migration to the spawning beds. The males develop long, sharp teeth, hooked jaws and a hump at the shoulders. The back and sides of the female become thin and the abdominal cavity distended with eggs.

At the spawning beds the adult pair construct a nest in the gravel by pushing on the bottom with their heads and the sides of their bodies. The female deposits the eggs in the nest and the male extrudes sperms over them. Both adults then soon die, never returning to salt water.

The eggs hatch in 40 to 180 days, according to the temperature of the water in which they are incubated. The fry are nourished for two months by the food in the yolk sac. When the yolk sac is nearly absorbed, they begin to swim about and feed on microscopic plankton, small crustacea and insects. They are then known as fingerlings.

Usually the fingerlings begin to drift down to the ocean as soon as they are able to swim. Chamberlain (4), Gilbert (14) and Rutter (43) mention cases of Chinook fingerlings that remain for a time in fresh water and migrate to the ocean as yearlings. Such fish are inferior in size to those that spend their first year in salt water.

Practically nothing is known about the life of the salmon in the sea except that they remain near the mouth of their parent stream during their first year. The Chinook salmon spends from 2 to 7 years in the ocean and usually returns to fresh water in 4 years. Gilbert (14), who made the above estimates of the age of the Chinook, based his figures on the marking of the scales. He finds that the growth of the scales is retarded during the winter and accelerated in the summer, and this periodicity of growth is recorded by the striations on the scale.

DESCRIPTION OF THE SPERM AND EGG

The head of the sperm of the Chinook salmon is 0.0026 mm. in length and tapers forward from the base, which is 0.002 mm. in diameter, to a blunt tip. A common length for a sperm is 0.0196 mm. from tip to tip.

The diameter of the eggs varies from 7 mm. to 9 mm. and averages 7½ mm. The weight of the living eggs examined varied from 0.26 grams to 0.33 grams, but not a sufficient number of eggs was weighed to give a reliable average. The live egg has a specific gravity greater than water and sinks to the bottom when laid. The freshly laid eggs are usually spherical, though often irregular in shape, owing to a crowded condition in the body cavity of the female before the eggs are deposited.

The zona radiata is a tough, elastic, semi-opaque membrane which covers the egg. In the specimen examined it was 0.0647 mm. thick. It contained canals similar to those described in the zona radiata of the trout by Henneguy (22). It is not adhesive like some of the egg membranes of the pelagic teleostean ova. A space exists below the zona radiata, leaving the egg enclosed by it free to move within. The disk of the living egg is always found uppermost, no matter in what position the egg is placed. The cavity is exaggerated in preserved eggs by the shrinkage of the yolk.

The bulk of the egg is composed of an albuminous yolk (*Fig.* 2) which is a transparent fluid in the living egg but is coagulated in the preserved egg into a transparent, hyaline mass. The albuminous yolk is homogeneous thruout and as far as could be determined has no structure.

Resting on the top of the yolk and embedded in it is a cap of globules (Fig. 2). This cap is about 4 mm. in diameter and from 1 to 2 mm. deep at the center. The globules in the living egg are spherical but are slightly distorted by preservation. The content of these globules is dissolved out in the pre-ovum, leaving vacuoles in the yolk (*Fig.* 4). These vary considerably in size. Those immediately beneath the disk are smaller than the ones farther from it (*Figs.* 3 *and* 4). They are also found elsewhere in a single layer on the surface of the yolk (*Fig.* 3).

These drops give the rosy color to the egg and resemble the globules in the tissues of the salmon that are mentioned by Greene (19). According to Henneguy (22), the content of these globules is some sort of oil. Prince (34) suggests that there is also lecithin in the content of the drops. Their function is not clear, although they persist in the yolk sac after hatching and are found in certain relations to the advancing germ ring. They probably furnish the developing fry with nutrient substance.

In the ovarian egg the granular substance is evenly distributed in a thin layer over the entire surface of the egg (*Fig.* 2). In the egg taken from the abdominal cavity of the female, the greater part of the germinal material is concentrated in a disk on the upper pole and rests upon the oil cap (*Fig.* 3). This disposition of the germinal substance is quite contrary to that in the sea bass (Wilson, 49) and the cod (Ryder, 36). In these pelagic eggs the granular material is not concentrated until fertilization is effected and then upon the lower side. The formation of the germinal disk is described for the trout by Henneguy (22) and is like that of the salmon as described above. The disk thus formed is lenticular in section and fades out at the periphery into a thin layer which extends superficially over the yolk.

SEGMENTATION

Owing to the opacity of the zona radiata, the delicate structure of

the ovum, and the fluid yolk, it is practically impossible to follow the segmentation in the living egg. Therefore the observations upon the cleavage and differentiation were made from preserved material. Inasmuch as all the eggs used in the discussion were fertilized at the same time and were kept under identical conditions, the age as well as the stage of development is used in the description of the segmenting egg. The water in which the eggs were kept varied in temperature from $7\frac{1}{2}°$ to $12°$ C. during the period of incubation.

Three hours after fertilization there is no appreciable change in the external appearance of the disk from that of the ripe unfertilized egg (*Fig.* 3). The disk in the 6-hour egg is set distinctly above the granular material lying on the yolk at the periphery of the disk. This condition remains in the segmenting egg until differentiation begins, when the margin of the disk again becomes fused with the granular substance adjacent to it on the yolk. The first cleavage furrow, apparent in the 6-hour egg, starts from the center of the disk and extends transversely across it to either side. This furrow has extended completely across the disk in the 8-hour egg (*Fig.* 5).

The second cleavage furrow, which is first noticed in the 10-hour egg, also starts from the center of the disk and extends meridionally at right angles to the first furrow (*Fig.* 6).

The fourth cleavage is parallel to the second and is complete in all 20-hour eggs. The disk at the end of the fourth segmentation is 1-layered (*Fig.* 7).

Twenty-three hours after fertilization the fifth cleavage is effected. This results in a 2-layered mass of cells (*Fig.* 8).

The sixth cleavage, at 26 hours, finds the disk still in two layers (*Fig.* 10). It has not been possible to trace the cleavages following the sixth.

The first cleavage furrow divides the disk into two blastomeres of equal size (*Fig.* 5). The four blastomeres resulting from the second cleavage are not equal in size (*Fig.* 6). Each succeeding cleavage results in a greater irregularity among the blastomeres until in the 16 and 32 cell disks, none of them is of the same size or shape (*Figs.* 7, 8, 9).

There is, however, an apparent bilaterality in the disk during at least the first five cleavages. The disk of the unsegmented egg is circular. The first segmentation produces a disk which is oval in shape, with the longer axis perpendicular to the first cleavage plane (*Fig.* 5).

This oval shape of the disk continues to the 26-hour stage when it becomes rounded again (compare *Figs.* 6, 7, 8, 10). Two circular disks were found among the the 23-hour eggs and one among the 20-hour eggs.

The first furrow is perpendicular to the long axis of the disk. It is deeper than the succeeding ones and so can be readily distinguished from them. It is often so distinct in the 32-celled stage as to form a disk shaped like a dumb-bell in surface view (*Fig.* 9). Three such disks were found among twenty-six 20-hour eggs examined.

Cavities exist between the cells of the 32-hour disk (*Fig.* 26). These might represent the segmentation cavity which later exists as the subgerminal cavity. The latter consists of a cavity between the blastoderm and the periblast. The periblast is a layer of granular material upon the surface of the yolk and filled with free nuclei. The subgerminal cavity of the 101-hour egg is shown in Fig. 27.

FORMATION OF THE BLASTODERM AND PERIBLAST

The first differentiation of the cells of the blastodisk appears in the formation of the blastoderm. It starts in the 32-hour disk. The superficial cells of the disk at this stage form an unbroken layer and are not markedly different from the cells covered by them. The marginal cells of the 32-hour disk are set above the surrounding germinal material (*Fig.* 26). The 44-hour disk contains many cells. The external cells are continuous with one another and are columnar in section. They are different from the other cells of the disk and fuse with the granular material superficial to the yolk. As the development of the blastodisk proceeds, the cells become smaller and finally in the 101-hour egg (*Fig.* 27) form a thin membrane which covers a mass of loose cells beneath it.

The formation of periblast nuclei is characteristic of teleost development. They were first described by Lereboullet (31) in 1854. Since that time these nuclei have been the object of the study of several authorities upon teleostean development. Their research has been directed along two channels, their origin and their physiological function.

In 1876 Klein (28), in a paper on the development of the trout, comes to the conclusion that they arise *de novo*.

Hoffman (23) offered an explanation of the origin of the periblast nuclei. He described the first nuclear division as being horizontal and resulting in the formation of two nuclei. The one adjacent to the yolk gave rise to the periblast nuclei and the other to the nuclei of the blastodisk. Agassiz and Whitman (1) criticized this theory and offered a more satisfactory solution to the problem. They found that nuclei present in the periblast were derived from the marginal cells of the blastodisk, and that they multiplied in the periblast by division. Wilson (49) finds evidence supporting this theory in the development of the sea bass. The yolk nuclei found in the Chinook salmon seem to be formed in this manner also.

The periblast of the salmon egg extends completely under the blastodisk at all stages of development. The periblast of the trout described by Henneguy (22) reached under the disk only slightly beyond the periphery of the disk.

The periblast nuclei in the salmon egg are seen in the granular material at the periphery of the blastodisk in the 44-hour egg. In the 72-hour egg the nuclei had undergone division and migrated under the disk about half way to the center. In the 101-hour egg they were scattered throughout the synctium formed by the periblast both under the disk and immediately beyond its margin. Division of the yolk nuclei is not accompanied by any division of the granular substance in which they are embedded.

FROM GASTRULA TO EMBRYO

As differentiation proceeds, certain changes are observed in the shape of the blastodisk. Hitherto lenticular in section and slightly convex, it now becomes concave in section. According to Sumner (44, 45), who received his idea from Götte, the change is accomplished by the migration of cells, causing a thinning of the cells in the center of the blastodisk, and a thickened area at the margin. A heavy band of cells is formed in this manner at the periphery of the disk, enclosing a lighter central area (*Fig. 14*). The shape of this area is clearly defined even in the unprepared preserved egg, since the peripheral band of cells constituting the germ ring is thicker and more opaque than the thinner area on the interior. Sections shows that this central area is but one cell thick in the 7-day egg.

An increase in the diameter of the blastodisk occurs simultaneously with the extension of the germ ring over the yolk. The germ ring is thickened at the point where the development of the embryo begins and this represents the primitive streak. Henneguy (22) describes it for the trout and Wilson (49) for the sea bass. This caudal knob remains at the posterior end of the embryo until the lips of the germ ring close (*Figs. 19-23*).

A group of undifferentiated cells, known as the secondary caudal mass, is left at the rear of the embryo when the germ ring has covered the yolk. According to Wilson (49), this is assimilated by the primitive streak. A shallow groove marks the fusion of the lips of the germ ring in the 13-day egg.

The germ ring is developed during the fifth day (*Fig. 14*) after fertilization, and the following day a thickening is noticed at the point at which the embryo develops later (*Fig. 15*). On the seventh day this thickening is more pronounced (*Fig. 16*), and a day later the primordium of the head appears (*Fig. 17, 18*). At this time the germ ring has extended one-fourth of the way over the yolk. On the ninth day the blasto-

derm covers one-third of the yolk, and two somites appear (*Fig.* 19). By the tenth day the germ ring has passed the equator of the yolk, and thirteen somites are found in the embryo (*Fig.* 20). The 12-day embryo has 33 somites (*Fig.* 22). The advance of the germ ring over the yolk continues until the thirteenth day, when the lips of the blastopore meet and the caudal end of the embryo has been formed (*Fig.* 23). The embryo at this time is 4 mm. long and contains 38 somites.

In the advance of the germ ring over the yolk a curious relation of it to a circle of large oil drops on the surface of the yolk was noticed. In the 5-day egg there was a ring of large oil drops beyond the edge of the blastodisk (*Fig.* 14). On the sixth day the germ ring had extended to the edge of this circle and a few of the globules were seen in Fig. 15 in the margin of the disk. The oil ring was found to be covered on the following day (*Fig.* 16), and the germ ring was directly over this ring of globules. It was found on the eighth day to be just under the inner edge of the germinal ring (*Figs.* 17, 18). Evidently the ring of oil drops remains stationary while the germ ring passes over it.

The period of concrescence covers that stage in fish development known to culturists as the tender or critical period, since slight handling of the eggs at this time will injure or kill the developing embryo. It lasted from the fifth to the fourteenth day under the conditions in which the eggs used in making the observation were kept. The critical period mentioned by Rutter (43) for the Quinnat salmon in the Sacramento lasted from the sixth to the sixteenth day, the difference probably being due to a difference in the temperature in which the eggs were hatched.

HATCHING AND FRY

Th egg of the salmon is large for a teleost and its rate of development is much slower than that of the smaller pelagic eggs. In the material under observation, hatching began from 45 to 52 days after fertilization, varying with the temperature. The hatching period, the time between the hatching of the first and last fish in a trough, was 19 days.

Hatching is immediately preceded by a physiological change in the zona radiata. The egg membrane, which is semi-opaque before the time of hatching, becomes transparent just as the embryo is ready to emerge. Also the tough membrane is tender and breaks readily at this period. Although four fish hatched from eggs in which this change had not taken place, they all died. The egg membranes from these eggs did not disintegrate in the water, but the membranes from those eggs cast from fish hatching normally all soon disappear.

The process of hatching involves the change in the membrane mentioned above and the actual emergence of the fish from the egg. The time

it takes for the fish to come from the shell is very short indeed if it is disturbed while hatching, but the time elapsing from the change in the zona radiata until the fish is free is at the most two hours.

The fish all thrived equally well, whether head, tail or body hatched first. In 82 eggs observed while hatching, 39 emerged from the shell head first and 43 tail first. The observations on the hatching of the Chinook salmon agree very well with those of White (48) on the brook trout except that the change in the zona radiata was not mentioned in that account.

The pectoral fins begin moving immediately before hatching. In one case the zona radiata was first pierced by the motion of these fins. Just after hatching the young fry lies quietly on the bottom on the side of its yolk sac and remains in that position for some time unless disturbed.

Fish just hatched lie quiescent on the bottom, only moving when disturbed, until the yolk sac is nearly absorbed. A slight jar on the side of the trough or a light tactual stimulus is sufficient to make the young fry move about.

The fish newly hatched, although possessing correlated muscular movement, is not able to swim in a straight line but swims in a spiral or crooked path when stimulated. The awkward movements of the young fry are due to the large mass of inert material in the yolk sac hanging from the body.

For about 60 days the developing fry live on food stored in the yolk sac. At the end of the time the yolk sac is absorbed and the fish begins to swim about, dart after food, rise to the surface and display all signs of being ready to feed on food external to its body.

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PLATE 73

c^1=first cleavage plane
c^2=second cleavage plane
c^3=third cleavage plane
cv=cortical vacuoles
gd=germinal disk
gs=germinal substance
oc=oil cup
og=oil globule
y=yolk
zr=zona radiata

Fig. 1.   Section thru entire ovarian egg. $\times$ 6.8.

Fig. 2.   Section thru entire 3-hour egg showing the germinal disk.
$\times$ 6.8.

Fig. 3.   Section thru 8-hour egg. 2-celled stage. $\times$6.8.

Fig. 4.   Surface view of 8-hour egg from above, 2-celled stage. $\times$ 6.8.

Fig. 5.   Surface view of 10-hour egg from above, 4-celled stage.
$\times$ 6.8.

Fig. 6.   Surface view of 20-hour egg from above, 16-celled stage.
$\times$ 6.8.
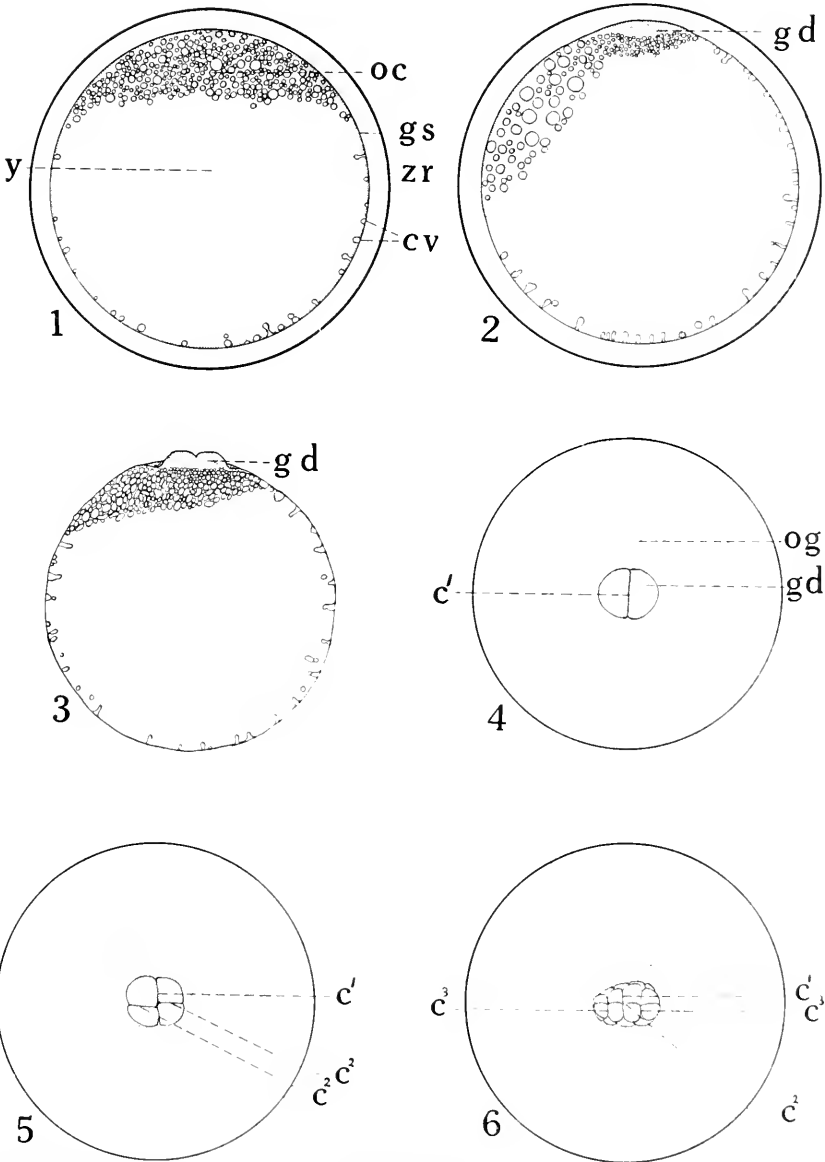
PLATE 74

bd=blastoderm
*c*¹=first cleavage plane
gd=germinal disk

Fig. 7.   Surface view of 23-hour egg from above. 32-celled stage.
× 7.6.

Fig. 8.   Surface view of 23-hour egg from above. 32-celled. dumb-
bell shaped.   × 7.6.

Fig. 9.   Surface view of 26-hour egg from above, 64-celled.   × 7.6.

Fig. 10.   Surface view of 32-hour egg from above, approximately
128-celled.   × 7.6.

Fig. 11.   Surface view of 44-hour egg from above, many celled.
× 7.6.

Fig. 12.   Surface view of 101-hour egg from above, showing blasto-
disk.   × 7.6.

7 g d

8 c′

9

10

11

12 bd
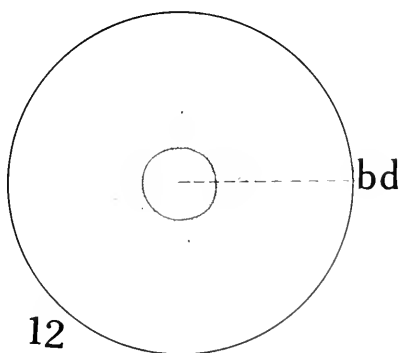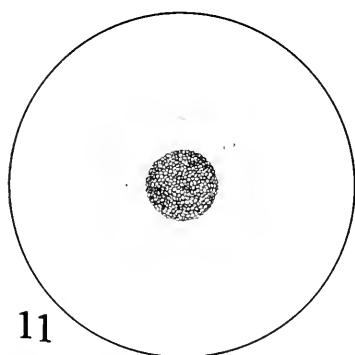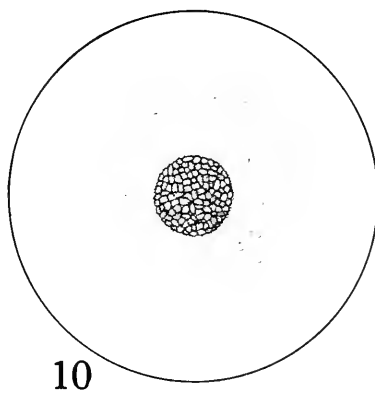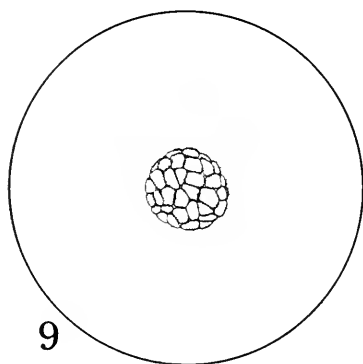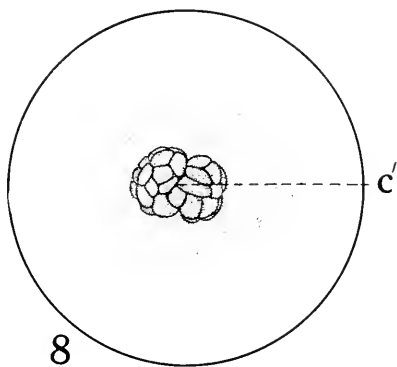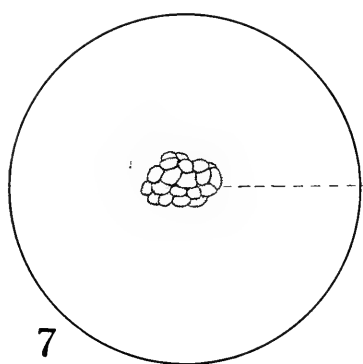
PLATE 75

bd=blastoderm
et=embryonic thickening
gr=germ ring
he=head end of embryo
ms=mesodermal somites
ov=optic vesicle
ps=primitive streak
y=yolk

Fig. 13. Surface view of 5-day egg from above; beginning of germ ring. × 7.6.

Fig. 14. Surface view of 6-day egg from above; germ ring; embryonic thickening. × 7.6.

Fig. 15. Surface view of 7-day egg from above; germ ring; embryonic thickening. × 7.6.

Fig. 16. Surface view of 8-day egg from above; germ ring; primordium of head. × 7.6.

Fig. 17. Surface view of 8-day egg from side; germ ring; primordium of head. × 7.6.

Fig. 18. Surface view of 9-day egg from side; germ ring advancing. × 7.6.
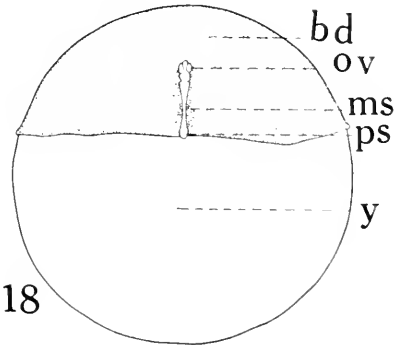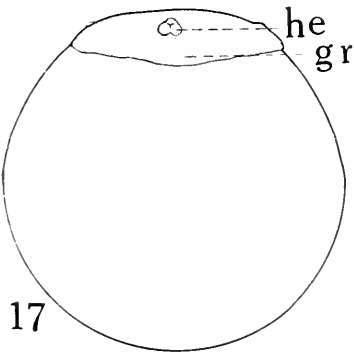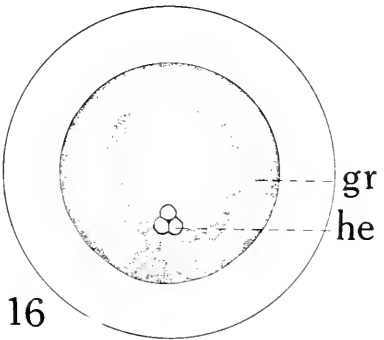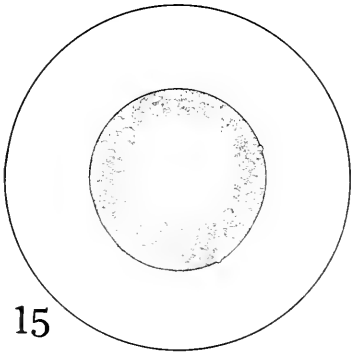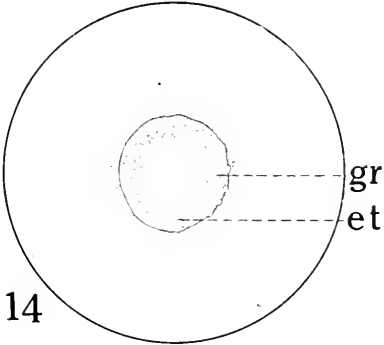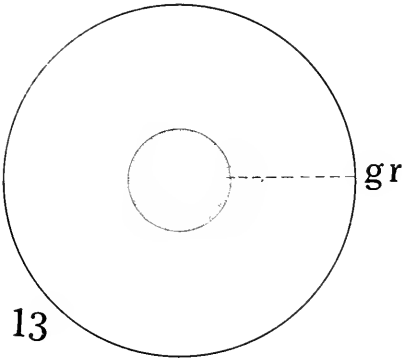
PLATE 76

as=auditory sac
bl=blastopore
bn=nuclei of blastoderm
gr=germ ring
ms=mesodermal somites
p=periblast
scm=secondary caudal mass

Fig. 19.   Surface view of 10-day egg from side; advancing germ ring; embryo. $\times$ 7.6.

Fig. 20.   Surface view of 11-day egg from side; advancing germ ring; embryo. $\times$ 7.6.

Fig. 21.   Surface view of 12-day egg from side; embryo; yolk blastopore. $\times$ 7.6.

Fig. 22.   Surface view of 13-day egg; embryo complete; blastoderm covering entire yolk. $\times$ 7.6.

Fig. 23.   Section thru 6-hour disk; 2-celled stage. $\times$ 43.8.

19   as
     ms
gr   gr

20

21   bl
     gr

22   scm

23   bn   p
     yv

M. C. Riddle, Del.   PLATE 76
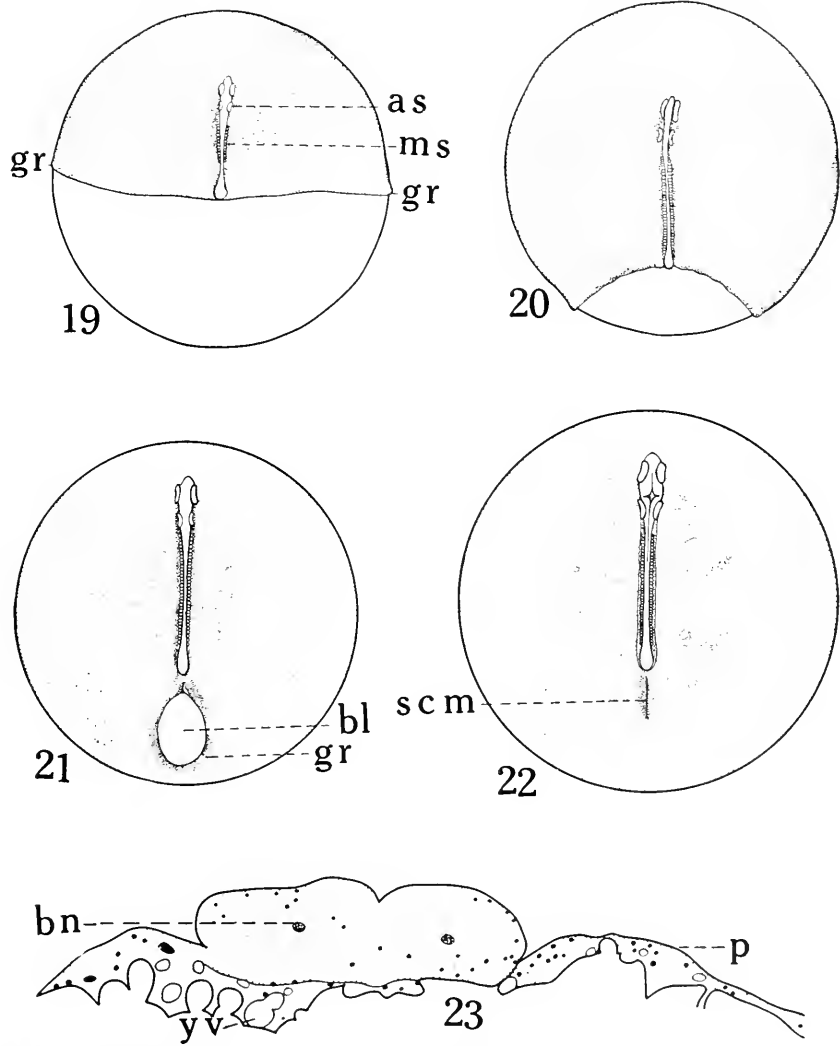
PLATE 77

bd=blastoderm
bn=nuclei of blastoderm
c¹=fourth cleavage plane
ic=intercellular cavity
p=periblast
pn=periblast nuclei
sc=subgerminal cavity
yv=yolk vacuoles

Fig. 24.   Section thru 20-hour 32-celled disk showing periblast without periblastic nuclei.   ×50.

Fig. 25.   Section thru 32-hour disk.   × 50.

Fig. 26.   Section thru 101-hour disk showing blastoderm, segmentation cavity, and periblast with scattered nuclei.   × 50.

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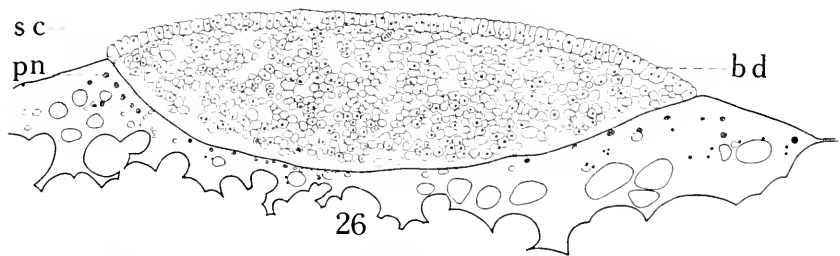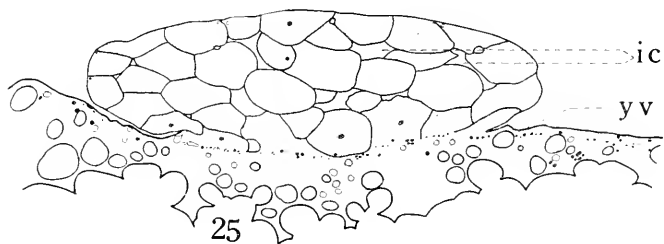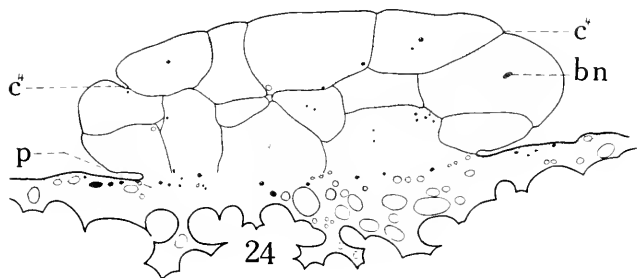
Winter Condition of Some Puget Sound Algae

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It is still uncertain whether all marine plants have seasonal life cycles; likewise whether those whose life history is influenced by the seasons are primarily affected by change in temperature or in light intensity. Davis (1911) observed the seasonal distribution of most of the algae found about Woods Hole, Massachusetts. He attributes it to the great variation in temperature of the water, ranging from 30° F. in February to 71° F. in August, with a mean temperature below 35° for January, February and March. That there is a seasonal marine flora just as there is a seasonal terrestrial flora is settled for a large number of species for certain regions, but with the significant difference that many forms are more luxuriant in the coldest months of the year and are killed or injured with the arrival of the warm season. Collins (1900) says that winter has no influence whatever below the low water mark. He thinks that the plants left in pools by the recessions of the tide are not inconvenienced by a freezing temperature so long as they are not solidified. He found reds, browns and greens growing in perfect condition under a covering of ice, mentioning especially *Ectocarpus* and the species of *Fucus*. While pointing out the seasonal occurrence of a number of species, he states that no generalizations can be made to cover them.

Because the climate of Puget Sound is so much milder it was thought that observations of the algae growing here in midwinter might show interesting differences between the winter flora of this coast and that of the colder Atlantic waters. It was also hoped that they would throw more light on the problem of seasonal distribution of marine algae in general. It is unfortunate that the writer cannot extend them over a longer period of time. As it is it must be emphasized that only the positive results are valuable, negative results meaning nothing on account of the limited number of collections. That plants were not found at a certain collection may not indicate that they were not there, but probably that an unfavorable time made it impossible to find them at that time. Also, since reports for the deep water forms are based solely on specimens washed up on the beach, it is obvious that success or failure in finding a plant might depend

en such a thing as the violence of a recent storm and not on the absence of the plant on account of a seasonal change.

Collections were made at Lincoln Beach and Fort Lawton, both in Seattle, and at a few other points on Puget Sound. The time extended from November, 1916, to April, 1917. The temperature of the water varies from 5° to 6° C. in winter to about 15° C. in the summer. It was desired to determine what species thrive here in the winter months, whether or not they reproduce all winter, and whether, in the case of the reds, there is a predominance of sexual or of asexual plants. The presence or absence of young plants, indicating the amount of germination of spores in winter was also noted. An increase in the number of young plants with the arrival of spring was specially looked for since it would indicate an effect of warmer weather or increased light intensity in producing periodicity corresponding to that of land plants.

TABLE 1.   *Winter conditions of the Rhodophyceae*

	Tetrasporic Plants	Carposporic Plants	Vegetative Plants	Young Plants
Agardhiella tenera (J. Ag.) Schmitz	*	*		*
*Antithamnion floccosum pacificum (Harv.) S. & G.	*			
Callophyllis variegata (Bory) Kuetz.		*		
Callithamnion sp.			*	
Centroceros sp.			*	
Ceramium californicum J. Ag.			*	
Ceramium rubrum (Hud.) Ag.			*	
Ceramium strictum (?) Harv.	*			*
Constantinea sitchensis P. & R.			*	*
Cryptosiphonia woodii (Harv.) Falk	*	*		*
*Dasyopsis plumosa (H. & B.) Schmitz				
Farlowia mollis (H. & B.) F. & S.			*	
Fauchea gardneri Setch.			*	*
Gigartina mamillosa (G. & W.) J. Ag.	*	*	*	
Gigartina radula exasperata (H. & B.) Setch.	*	*		*
Gracilaria confervoides (L.) Grev.	*	*		*
Iridaea laminarioides Bory	*	*		*
Laurencia pinnatifida (Gmel.) Lam.			*	
Microcladia californica Farlow			*	
Nitophyllum latissimum (Harv.) J. Ag.	*	*		*
Nitophyllum ruprechtianum J. Ag.			*	*
*Odonthalia aleutica (Ag.) J. Ag.		*		
Platythamnion heteromorphum typicum S. & G.			*	
Plocamium coccineum (Hud.) Lyng.			*	*
*Polysiphonia californica Harv.	*	*		
Polysiphonia urceolata (Litf.) Grev.	*	*		*
Porphyra perforata J. Ag.			*	*
Prionitis lyallii Harv.	*	*		*
Pterosiphonia baileyi (?)			*	
Pterosiphonia dendroidea (Mont.) Falk			*	
*Rhodomela larix (Turn.) Ag.	*	*		
Rhodomela lycopodioides (L.) Ag.			*	
Rhodymenia palmata (L.) Grev.				*
Rhodymenia pertusa (P. & R.) J. Ag.			*	*
Sarcophyllis californica J. Ag.	*			

*Antheridial plants found.

Tables 1 and 2 are a list of all algae found growing in a healthy condition in December, 1916, and January and February, 1917, together with a record of their reproduction and the presence of young plants. The observations are not separated by months because the failure to find a certain form in any one month could not always be taken to mean that it was no longer growing.

TABLE 2.   *Winter condition of the Phaeophyceae and Chlorophyceae*

	Reproducing Plants	Vegetative Plants	Young Plants
Desmarestia ligulata herbacea (Turn.) J. Ag................		*	
Ectocarpus granulosus (Engl. Bot.) Ag.	*		
Ectocarpus siliculosus Kuetz.	*		
Fucus evanescens Ag.	*		*
Nereocystis luetkeana (Mert.) P. & R.	*		*
Phyllitis fascia (Muel.) Kuetz.		*	*
Punctaria latifolia Grev.		*	*
Pylaiella littoralis (L.) Kjell.	*		
Cladophora arcta (Dill.) Kuetz.		*	*
Enteromorpha intestinalis (L.) Link.......................		*	*
Enteromorpha linza (L.) J. Ag.		*	*
Ulva lactuca L.			*

Of these Puget Sound algae Davis (1911) reports only the following as actually found growing at Woods Hole in winter: *Ulva lactuca, Phyllitis fascia, Ectocarpus granulosus,* and *Ectocarpus siliculosus.* He found other species of *Porphyra, Fucus* and *Cladophora.* He gives as spring or summer forms a considerable number which were found mature in Puget Sound in midwinter, viz., *Enteromorpha linza, Polysiphonia urceolata, Cladophora arcta, Desmarestia aculeata, Fucus evanescens, Ceramium strictum* and *Gracilaria confervoides,* besides other species of *Antithamnion, Callithamnion, Rhodymenia* and *Rhodomela.* Howe (1914) found only a "battered and weather-worn fragment" of *Agardhiella tenera,* a "denuded" *Desmarestia aculeata,* and among others, specimens of *Ceramium rubrum* and *Polysiphonia urceolata formosa.* This leaves a considerable number of the Puget Sound algae which have not yet been reported as winter forms.

One may classify the algae of table 1 on the basis of their reproduction into the 6 groups below, of which group 5 constitutes those so commonly found that it can be fairly concluded that they do not ordinarily reproduce in winter, group 6 those found so rarely that the absence of reproducing specimens does not mean much.

Group 1. Species reproducing both sexually and asexually all winter:
Agardhiella tenera, Gigartina mamillosa, Gigartina radula exasperata, Gracilaria confervoides, Iridaea laminariodies, Nitophyllum latissimum, Polysiphonia californica, Polysiphonia urceolata, Rhodomela larix, Cryptosiphonia woodii, Prionitis lyallii.

Group 2. Tetrasporic and vegetative plants:
Antithamnion floccosum pacificum, Ceramium strictum, Sarcophyllis californica.

Group 3. Carposporic and vegetative plants:
Odonthalia aleutica, Callophyllis variegata.

Group 4. Antheridial plants:
Antithamnion floccosum pacificum, Dasyopsis plumosa, Odonthalia aleutica, Polysiphonia californica, Rhodomela larix.

Group 5. Vegetative plants only:
Rhodymenia palmata, Ceramium californicum, Ceramium rubrum, Constantinea sitchensis, Farlowia mollis, Fauchea gardneri, Microcladia californica, Plocamium coccineum, Porphyra perforata, Pterosiphonia baileyi, Rhodymenia pertusa.

Group 6. Species found too rarely to classify:
Callithamnion sp., Centroceros sp., Laurencia pinnatifida, Platythamnion heteromorphum typicum, Pterosiphonia dendroidea, Rhodomela lycopodioides.

It is probable that those in groups (2) and (3) might have been placed in group (1) had there been a greater number of specimens available for examination. For instance, in the case of *Antithamnion* in groups (2) and (4), in which tetraspores and antheridia were found, it seems improbable that oogonia were not also produced at this season. It is also probable that *Odonthalia aleutica* and *Callophyllis variegata* might be found with tetraspores, although it is true that a considerable number of plants of the former were examined without finding any tetrasporic ones. The small number of antheridial plants found indicates merely that the male plants are rare. Groups 1 to 6 above show that the majority of the plants which thrive in winter produce spores in winter, but it also shows that some (group 5) do not. Evidently the colder weather, while permitting vegetative growth, is not conducive to reproduction in some of the winter species.

The spores of a large proportion of species either germinate in winter, or else produce young sporelings which remain quiescent and are found in considerable numbers during the coldest months. This may be either evidence of the lack of an inhibiting factor so that spores can germinate at any time, or of the presence of an inhibiting factor that prevents the maturing of the sporelings until a later season. Growth records of individual plants should be taken to show which is the case.

Lewis (1912) reports that at Woods Hole *Polysiphonia violacea,* *Dasya* and *Griffithsia* sporelings grew very little after August 15, and by September 1 were disintegrating. In a later paper he says that *Polysiphonia violacea* plants which have attained any considerable size, die at the approach of cold weather while the young tetrasporic sporelings are dormant during the winter. Thus at Woods Hole *Polysiphonia* is present in winter only as young tetrasporic sporelings, the plants found in early summer are tetrasporic and those of the late summer are sexual. Lewis found only one plant out of ten to be sexual in July, while in August the majority were sexual.

Observations at Lincoln Beach show that this seasonal life cycle does not hold for the Puget Sound species, since large healthy plants were abundant all winter. Some of these were sexual and some tetrasporic. Nearly all of the cystocarps found in winter were very young, many with the trichogyne still attached. In *Polysiphonia californica* the tetrasporic plants predominate early in February, but later the number of tetrasporic and carposporic plants is about the same. This is shown by the following data:

Feb. 12, Lincoln Beach: 12 tetrasporic, 0 carposporic, 0 antheridial, 0 sterile.
Feb. 24, Lincoln Beach: 35 tetrasporic, 5 carposporic, 3 antheridial, 5 sterile.
Feb. 28, Fort Lawton: 4 tetrasporic, 8 carposporic, 1 antheridial, 5 sterile.
Mar. 25, Lincoln Beach: 8 tetrasporic, 9 carposporic, 3 antheridial, 5 sterile.
Apr. 22, Lincoln Beach: 5 tetrasporic, 4 carposporic, 1 antheridial, 2 sterile.

Thus until February 24, the number of tetrasporic plants of *P. californica* greatly exceeded the number of carposporic ones; but by the end of March there were practically the same number of each. This, together with the observation that the cystocarps were all young, suggests that although the life histories of the Puget Sound plants do not follow those of Woods Hole in point of seasonal occurrence, the two generations may be at least partly conditioned by the season. No sexual plants of *Polysiphonia urceolata* were found. The majority were sterile, the rest tetrasporic.

Lewis (1914) considers the seasonal life cycle of *Polysiphonia* characteristic of many New England algae, mentioning *Agardhiella, Champia, Grinnellia, Chondria* and Atlantic species of *Polysiphonia.* He says that *Agardhiella* shows the two generations clearly separated in point of time, all the larger individuals being killed at the approach of winter. This is an interesting contrast to conditions in Puget Sound in which large specimens of *Agardhiella* were found all winter, and both cystocarpic and tetrasporic individuals were found in equal numbers. The same is true of a considerable number of red algae found reproducing here both asexually and sexually all winter (see group 1, page 344).

On account of the lack of change in the number and condition of the plants at Lincoln Beach from November 10 on through the winter, it was thought possible that the change of season might have no effect on the algal vegetation of Puget Sound; but with the advent of spring, changes were apparent in the condition of some species, which show that there are seasonal periods in at least some of the algae here. The most striking change was in the appearance or increased number of young plants, indicating a renewal of growth. The greater number of species found had young plants coming up near the older plants all winter long (tables 1 and 2). Other plants, notably the Laminariaceae, were either not found at all during the winter, or else were old and battered. Rigg (1917) has recorded the condition of *Nereocystis* in winter. His conclusions concerning the plant's seasonal periodicity and the appearance of the young plants in early spring are confirmed by my observations that young plants although not found at all during the winter were quite common in March and April. The same is true of *Costaria costata, Laminaria bullata* and *Laminaria saccharina*. On March 25 these young Laminariaceae were under six inches, in April they were mostly considerably more than 6 inches long. By April, young plants of *Scytosiphon, Phyllitis* and *Punctaria* were rare, these species starting to grow in February. Since the change in the temperature of the water is so slight at the depth at which *Nereocystis* grows, it seems probable that light intensity is responsible for its periodicity.

Although no *Soranthera* was found during the winter, young plants from the size of a pinhead to the size of a marble were abundant on April 22. Occasional plants were reproducing. In *Iridaea, Prionitis, Gigartina mamillosa, Fucus* and *Ulva*, an increase in the number of young plants was noticeable in March, although young ones had been more or less common all winter.

Fucus has a very evident periodicity. Scattered plants were found all winter. Their persistence from the previous season was evident from their coriaceous texture and dark color. The ends of the branches remained flat and leafy until the end of January or the first of February, showing no sign of the receptacles so characteristic of the plant in summer time. On February 4 the branches were still flat, but with the ends dotted with young conceptacles. On February 24 the ends had become distinctly swollen but were still light colored and young. These scattered plants are evidently stray ones which failed to complete their growth in the normal period; for the rocks were covered with young plants in March, and these were reproducing abundantly by summer.

Rhodymenia pertusa was not found reproducing during the winter but on April 22 all of the half dozen specimens found were dotted with young cystocarps or tetrasporangia.

Regeneration seems to be a more common phenomenon in winter than in summer, judging from the common occurrence of young fronds starting out from the surface of the old frond in several species. This was true of *Nitophyllum ruprechtianum, Gigartina mamillosa, Gigartina radula, Prionitis lyallii,* and *Fucus evanescens.* These young branches were very often in clumps on the flat surface of the old blade, evidently where the plant had been wounded.

<div align="center">SUMMARY</div>

1. The winter flora of Puget Sound is not markedly different from its summer flora. The few changes with the arrival of spring are for the most part the appearance of young plants of the summer forms.

2. A number of algae reported from the Atlantic coast as summer forms only, are present in Puget Sound all winter.

3. The algae with a conspicuous seasonal periodicity, as shown by the appearance of plants in spring which were not present in winter, are *Nereocystis luetkeana, Costaria costata, Laminaria bullata, Laminaria saccharina, Soranthera ulvoidea, Desmarestia aculeata, Scytosiphon lomentarius,* and *Odonthalia floccosa.*

4. Young plants of certain species were found more or less commonly all winter but in greatly increased numbers in March, viz., *Iridaea laminarioides, Prionitis lyallii, Gigartina mamillosa, Fucus evanescens* and *Ulva lactuca.*

5. While a large number of red algae reproduce all winter, a considerable number were found only in the vegetative condition.

6. Fucus plants do not reproduce in winter, the tips, with few exceptions, remaining flat until February.

7. Although *Agardhiella* and other red algae are reported from the Atlantic coast as having sexual and asexual generations occurring at different seasons, a large number, including *Agardhiella* and *Polysiphonia,* were found producing both sexual and asexual spores all winter.

8. The increase in the relative numbers of carposporic plants of *Polysiphonia californica* toward the end of the winter, and the young condition of most of the cystocarps found in the winter months, would suggest that there is at least a partial seasonal separation of the two generations.

CITATIONS

1900.   Collins, F. S.   Seaweeds in winter.   Rhodora 2: 130-132.

1911.   Davis, B. M.   Biological survey of the waters of Woods Hole and vicinity.   Bull. U. S. Bur. Fish.   31: 795-833.

1914.   Howe, M. A.   Some midwinter algae of Long Island Sound. Torreya 14: 97-101.

1912.   Lewis, I. F.   Alternation of generations in certain Florideae. Bot. Gaz. 53: 236-242.

1914.   ————   The seasonal life-cycle of some red algae at Woods Hole.   Plant World 17: 31-35.

1917.   Rigg, G. B.   Seasonal development of bladder kelp.   Puget Sound Marine Sta. Pub. 1: 309-318.

Brachyura and Crab-like Anomura of Friday Harbor, Washington

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This paper is based on (a) material collected by the writer during the summer of 1916, and (b) the examination of material collected by others during previous summers. In case a species has not been found by the writer, but has been reported from the vicinity by others, without the writer having seen the specimens, the fact is mentioned.

The papers most helpful in the preparation of this article are the key to the genera of the Lithodidae by Holmes (1900), and the Brachyura and Macrura of Porto Rico by Rathbun (1900a). However, others of the most useful works are included among the citations without direct references to them.

Acknowledgments are due to Professor Trevor Kincaid and Dr. Nathan Fasten of the University of Washington, and to Miss Mary J. Rathbun of Washington, D. C.

ORDER DECAPODA

KEY TO THE SUB-ORDERS

A. Body laterally compressed; abdominal legs all present, well developed, used for swimming. (NATANTIA. Not included in this paper.)

AA. Body not laterally compressed; abdominal legs often reduced or lacking, not used for swimming. REPTANTIA (p. 349)

Sub-order Reptantia

KEY TO TRIBES

A. Carapace not fused with epistome; last pair of trunk legs weak, folded over the carapce or under the abdomen; second antennae external to the eye. ANOMURA (p. 350)

AA. Carapace fused with the epistome; last pair of trunk legs not weak nor folded over the carapace nor under the abdomen; second antennae not external to the eye. BRACHYURA (p. 357)

Tribe *Anomura*

KEY TO FAMILIES

A.   Crab-like species.

    B.   Antennae usually as long as the chelipeds; last pair of trunk legs placed over the carapace.   PORCELLANIDAE (p. 350)

    BB.   Antennae not as long as the chelipeds; last pair of trunk legs not placed over the carapace.   LITHODIDAE (p. 351)

AA.   Shrimp-like species.   (Not included in this paper.)

Family PORCELLANIDAE

Genus Petrolisthes

1.   **Petrolisthes eriomerus**   Stimpson.   FLATTOPPED CRAB, PORCELAIN CRAB
(FIG. 4)

Rostrum or interantennal area rounded, bent slightly downward with median groove; antennae without setae, very long, in some instances twice the length of the carapace or the same length as the cheliped. Carapace flattened, slightly longer than wide; surface quite smooth or with a few very slight depressions and elevations, in some quite spotted, in others marked with more or less irregular broken transverse lines, usually two little bluish spots on either side of the median line near the posterior end. Maxillipeds large, joints very irregular and much flattened, inner margin fringed with long silky hairs which are most abundant on dactyl and propodus; ischium with a sharp spine-like projection on the outer side of distal end; merus lobed at middle of inner side; carpus and propodus convex on inner side. Chelipeds very large for size of carapace; hand triangular; inner margin of dactyls smooth but distal ends sharp and beaked; dorsal surface slightly roughened; carpus elongated and roughened by a row of teeth on the outer edge which project anteriorly; merus with rounded projection on the inner distal surface. First three pairs of walking legs somewhat hairy; merus quite flattened. Fifth pair of walking legs rudimentary, folded up over the carapace. Color greenish brown flecked with reddish brown spots on carapace and chelipeds; chelipeds and portions of carapace often bluish. First 3 pairs of walking legs banded with light gray markings.

It is found on rocky shores at extreme low tide under rocks, crowded down among finely broken pieces of rocks, barnacles and shells. Abundant on northeast corner and south end of Brown Island (8); also at Newhall's dock (5) and at all the rocky points between the Station (5) and Friday Harbor (4) docks; found in 25 fathoms off Canoe Island (16).
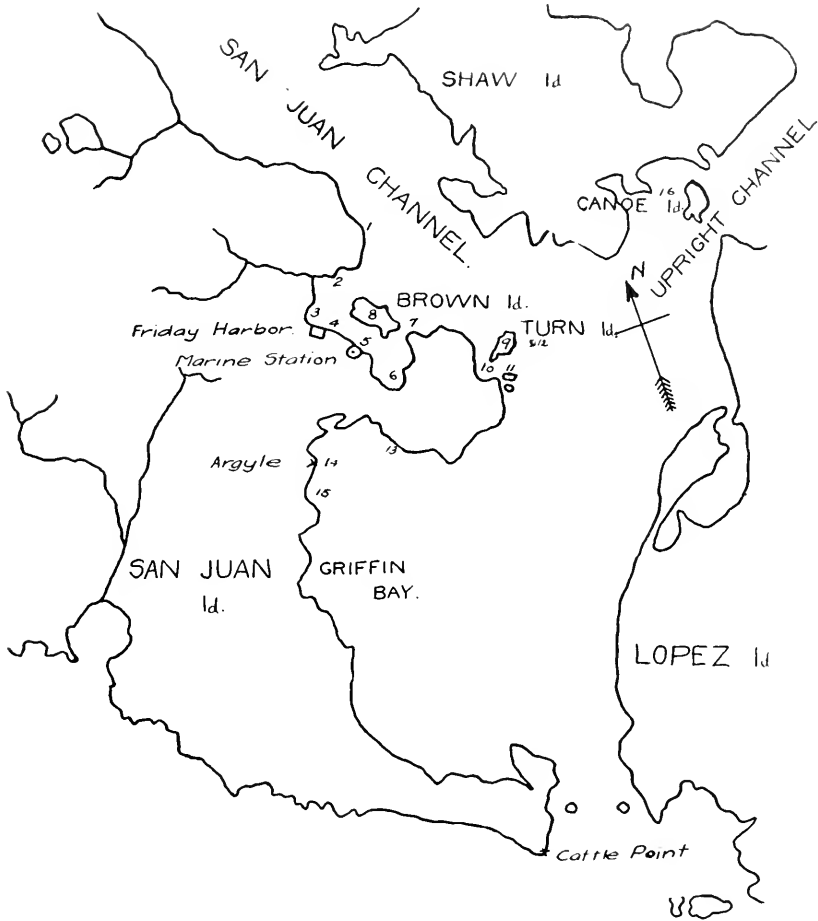
PLATE 78

Map of the Friday Harbor region. The numbers refer to regions where collections were made and are referred to in the body of the paper.

Family LITHODIDAE

KEY TO GENERA

A. Carapace produced laterally into two wings which conceal the walk-
ing legs, smooth.   CRYPTOLITHODES (p. 352)
AA. Carapace not so produced, not smooth.
  B. Carapace without spines or tubercles above but hairy.

                                               HAPALOGASTER (p. 352)
  BB. Carapace with spines or tubercles above.
  C. Carapace with deep pits above.

D.   Rostrum bifid.   PHYLLOLITHODES (p. 354)
DD. Rostrum not bifid.   RHINOLITHODES (p. 354)
CC. Carapace without deep pits.
E.   Abdomen membranous; carapace spiny.

ACANTHOLITHODES (p. 355)
EE. Abdomen with calcareous plates; carapace tubercled.

LOPHOLITHODES (p. 356)

Genus Cryptolithodes

1.   Cryptolithodes typicus Brandt. BUTTERFLY CRAB, TURTLE CRAB (FIG. 5)

Rostrum broad, rectangular, curved slightly downward, not distally widened. Eyestalks enlarged at base and curved upward. Antennular scales flat, leaf-like, irregular in form. Carapace very wide, with edges so extended and deflexed as to form a shield completely covering the whole animal, uneven in elevation, tubercled on the wing expansions at the joining of the anterior-lateral and posterior-lateral margins; median ridge extending from the rostrum to the posterior part of the body; teeth obscure, those on antero-lateral margin small; blunt tubercles on edge much more prominent in the older than younger specimens. Abdomen crossed by transverse lines. Chelipeds varying greatly in size; hands warty, with elevations in longitudinal rows with stiff hairs, with a large elevation on distal end of propodus and one on proximal end of dactyl. Walking legs rough; last pair folded in branchial chamber. Color blackish brown on dorsal side, light gray on ventral side. Largest specimen examined was 52 mm. wide and 43 mm. long from tip of rostrum to posterior margin.

Two specimens at 7 fathoms between Turn Island (9) and San Juan Island (10); also one at 7 fathoms off Canoe Island (16). Not abundant.

Genus Hapalogaster

1.   Hapalogaster mertensii Brandt.   (FIG. 6)

Rostrum a short sharp spine, not as long as the eye-stalk. Antennules short, thick. Antennae longer than the carapace, banded, slightly hairy; antennular scale a short horny spine. Carapace roughly heart-shaped; marginal teeth from anterior almost to posterior end, curving toward the anterior end, small at the posterior end, gradually increasing in size until quite prominent at anterior end, all but one posterior to cervical groove with tufts of stiff bristles from their tips; cardiac groove deep, extending to margin, dividing carapace into two portions; posterior portion very much broader than anterior; whole surface covered with tufts of stiff erect bristles, with a fringe of soft hairs bordering the posterior margin. Abdomen soft and sac-like, not completely folded under the thorax, dorsal and ventral surface of abdomen covered with tufts of

hairs similar to those on the carapace. Male abdomen extending to attachment of chelipeds, female as far as mouth parts; female abdomen with a pair of pleopods near posterior margin. Maxillipeds long; propodi with rounded lobes on outer margin; dactyls long, clavate; both these segments have long tufts of silky hair from the outer margin; carpus short; inner margin concave, outer convex, slightly hairy; ischium with a projection on inner surface; chelipeds unequal in size; merus of large cheliped slightly hairy, 4 spines in front, 2 large ones in the middle, and a smaller one on each side. Carpus and hand have rows of spines, the large spines on the outer margin of the hand. Small hand with 4 spines on outer border and 3 on inner edge. Walking legs quite flattened, covered with tufts of coarse hairs, without spines except on dorsal anterior edge and at some of the joints; ventral sides of walking legs quite smooth; dactyls small, black-tipped, sharp clawed, with a row of fine teeth on the posterior margin. Color brownish-red or grayish brown, in either case the legs are quite red on the ventral side.

Found along rocky shores at extremely low tide under rocks. Eight were found on the northeast corner of Brown Island (8) and an immature one on Turn Rock (12).
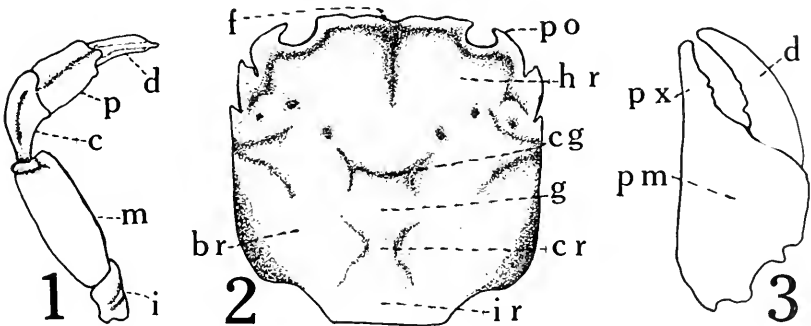
PLATE 79

Hemigrapsus nudus, used to illustrate some general parts of crabs; all drawings $\times$ 1.

Fig. 1.   Thoracic leg; *c,* carpus; *d,* dactyl; *i,* ischium; *m,* merus; *p,* propodus.

Fig. 2.   Dorsal view of carapace; *br,* branchial region; *cg,* cervical groove; *cr,* cardiac region; *f,* front; *g,* gastric region; *hr,* hepatic region; *ir,* intestinal region; *po,* postorbital tooth.

Fig. 3.   Cheliped; *d,* dactyl; *pm,* palm; *px,* pollex.

Genus **Phyllolithodes**

1. **Phyllolithodes papillosus** Brandt.   (FIG. 7)

   Petalocerus bellianus White.

"Carapace triangular and covered with strawberry-like tubercles which form a smaller elevated triangle whose sides are parallel to sides of carapace; a pair of large deep pits on the dorsal surface. Rostrum prominent, divided into two blunt, diverging, obliquely compressed horns, and bearing on the upper side a high bilobed crest. On the under side of the rostrum there is a spiny process directed forwards and curving slightly upwards, above the base of which is a pair of much smaller spines. Antero-lateral margin constricted behind the hepatic regions. A subacute spine at the outer orbital angle which is directed forwards, downwards, and slightly inward; two spines of unequal length just external to the post orbital; behind the constriction, the antero-lateral margin is armed with three long, slender, rather blunt spines which exceed the anterior ones in length. The postero-lateral angles of the carapace are produced outwards into flattened expansions which bear three blunt projections, the anterior one of which is elongated, slightly compressed, projecting upwards, outwards, and forwards; the posterior projection is short and rounded. Posterior margin of carapace transverse and furnished with a row of rounded tubercles. Antennal acicle furnished with three smooth flattened subequal spatulate processes. The chelipeds are unequal and thickly covered with long slender, more or less compressed, blunt spines, which are longest on the merus and carpus and gradually diminished in size toward the top and lower margin of the hand; the two hands are similar, fingers stout, corneous tipped and excavated, the outer sides furnished with numerous tufts of setae. Ambulatory legs subequal, subcylindrical, and thickly covered with long spines similar to those of the chelipeds. Basal abdominal segment nearly vertical and deeply pitted on either side like the following segments.

Length of carapace from tip of rostral horn, 52 mm.; width between tips of postero-lateral horns 51 mm." (Holmes, 1900).

Found on rocky shores at extremely low tide. None was found during the summer of 1916. They were found by Dr. Nathan Fasten on the northeast side of Brown Island (8) in the summer of 1915.

Genus **Rhinolithodes**

1. **Rhinolithodes wosnessenskii** Brandt.   GRAY-BEARDED CRAB (FIG. 11)

Rostrum blunt, short, with a serrated spur extending toward the front and ventral to the rounded knob. Eyestalks spurred on the dorsal surface. Second antennae long, slender, set below the first; antennular

acicles beset with little spurs similar to those on the eyestalks. Carapace roughly triangular in shape; large elevations just posterior to the rostrum; tubercles few, in groups; 7 little groups of dark colored ones on points at posterior angles; hairs few, stiff; cervical groove greatly depressed, extending in curves towards posterior edge, forming an oblong raised portion which looks much like the abdomen of a spider; margin with 9 or 10 uneven spines and a fringe of hairs. Chelipeds stout, thick, their hairs reddish with tan tips; carpus with 1 long stout spine; merus with two stout spines close together but divergent distally; dactyls hooked, rough on inner margin. Walking legs covered with coarse spines and bunches of hairs which are grouped about spines, hairy the whole length even on the dactyls, color of the carapace grayish-tan with orange markings in the depressions on the dorsal side, on the tubercles of posterior part of carapace, and on abdomen and branchial region. Legs are not highly colored but grayish tan like the general color of carapace.

They prefer rocky and shell bottoms and have been found at depths from 22½ to 40 fathoms. One was reported by Perry (Puget Sound Marine Station Pub. 1:175-176. 1916) in the summer of 1915 off Point Caution (1) at a depth of 40 fathoms. Professor Kincaid has obtained several specimens in Griffin Bay. Only one specimen was obtained during the summer of 1916. It was secured off Canoe Island (16) in 30 fathoms of water with much mud and algae.

Genus Acantholithodes

1. Acantholithodes hispidus (Stimpson) Holmes.   (FIG. 10)

"Carapace flattened lyrate, covered with long setose spines, which become somewhat larger towards the margins. Median region tumid and separated from the cardiac by a very deep transverve sulcus; a prominent depression between the median and branchial regions. Rostrum quite large and ending in three spines; a large fourth spine above and behind the median one. Eye peduncles hispid and retractile against the anterior margin of the carapace. Antennules large. Antennae shorter than the carapace; first basal joint with a spine on either side; second joint produced into a long acute process whose outer margin is armed with four or five spines; acicle narrow, acuminate, armed externally with numerous spines about equalling the lower spiny process. Ischium of the maxillipeds with two small subconical teeth on the outer surface near the antero-internal angle; merus hispid, not dilated, and longer than the ischium; last joint of the palp flattened below. Chelipeds unequal, very spiny; 2 or 3 very large spines on the anterior margin of the merus and carpus; in the larger hand the palm is inflated, the fingers deflexed, shorter than the palm, excavated within, corneous tipped, are more extensive and furnished with

calcareous molar-like teeth. In the smaller hand the palm is not so strongly inflated, the fingers are longer and straighter and more deeply excavated within; the corneous tips are more extensive and the calcareous teeth are smaller and more numerous. Ambulatory legs spiny, somewhat compressed; dactyls about two-thirds the length of the propodi. Abdomen short, broad, and soft, spines not so large as on the carapace; on the basal segment there is a median plate and two wide lateral ones; the plate on the penultimate segment is oblong; the last one is small, rounded, and about as long as wide. Length of carapace from tip of rostrum, 58 mm.; width of carapace, 58 mm." (Holmes, Occas. Papers of Calif. Acad. Sci., VII., pp. 120-121.)

According to Arnold (Sea Beach at Ebb Tide), this form is a deep water species and has been brought ashore at Monterey, California, by fishermen who have found it in the stomachs of fishes. Miss Rathbun reports it for Puget Sound. It ranges in depths up to 16 fathoms.

Prof. O. B. Johnson of the University of Washington has left a mounted specimen labeled "Friday Harbor" in the University Museum.

Genus **Lopholithodes**

KEY TO SPECIES

A.　Without foramen between chelipeds and first walking legs.

1.　*L. mandtii*

AA.　With foramen between chelipeds and first walking legs.

2.　*L. foraminatus*

1.　**Lopholithodes mandtii** Brandt.　　　　　KING CRAB (FIG. 12)

Echinocerus cibarus White; *Ctenorhinus setimanus* Gibbons; *Echinocerus setimanus* Stimpson.

Rostrum of 1 large conical prong with 2 lateral spines arising above at its base and 1 shorter one filling in the space between the lateral ones; all tipped with yellow. Antennules short and thick. Exopodites of antennae triangular, covered with stout thorns. Eyestalks thickly beset with spines. Carapace very rough, whole surface covered with tubercles of various sizes; with 3 large cones just posterior to cardiac groove, 1 median, 2 lateral; median region prominent; posterior marginal line with two large knobs which are posterior to and in line with the lateral ones on the side of the cardiac groove. Chelipeds short and stout; upper margin of hands armed with stout spines, more on the larger than the smaller hand; carpus with large triangular very spiny projections extending inward. Merus likewise with a prominent spur extending from inner margin. Walking legs covered with large projections dorsally, not spiny but

tubercled ventrally, the last pair rudimentary and folded in the branchial chamber; dactyls thick, spiny, dark colored. Color very brilliant, scarlet or orange, with bright purple markings particularly on ventral part of the body and the spines on the legs.

In 1915 six were secured, but in 1916 only 1, a male. This male was found in North Bay near Argyle (14) at 9 fathoms. Its width from spine to spine across the cardiac groove was 260 mm.; its length from the tip of the rostrum to the posterior edge of the carapace was 220 mm. Not abundant.

2. **Lopholithodes foraminatus** Stimpson   (NOT FIGURED)

Echinocerus foraminatus Stimpson.

Very similar to *L. mandtii;* carapace much more depressed; cone-like projections on back not so prominent. The most striking feature of this species is the circular opening formed by the depression in second joint of the cheliped, and one opposite it in the first pair of walking legs. These openings are prominent when the feet are folded in front of the carapace.

None was found during the season of 1916, but have been found in previous summers in North Bay (15) near Argyle (14) in about the same habitats as *L. mandtii*. Not abundant.

Tribe *Brachyura*

KEY TO FAMILIES

A. Carapace usually quadrilateral; verges of male inserted either in sternal plastron or basal joints of the fifth pair of legs.

   B. Carapace hard and firm; front, orbits and eyestalks not very small; buccal frame quadrate anteriorly; species of moderate size.

                                     GRAPSIDAE (p. 358)

   BB. Carapace more or less membranaceous; front, orbits and eyestalks very small; buccal frame arcuate anteriorly; species small.

                               PINNOTHERIDAE (p. 359)

AA. Carapace not quadrilateral; verges of males inserted in basal joints of fifth pair of legs.

   C. Carapace broad, short, rounded anteriorly; rostrum not projecting.

      D. Antennules folded longitudinally; front with several teeth, of which one is median.   CANCRIDAE (p. 363)

      DD. Antennules folded obliquely or transversely; front with or without median tooth.   PILUMNIDAE (p. 367)

   CC. Carapace usually triangular; rostrum projecting, pointed or spined.

                                    MAIIDAE (p. 367)

Family GRAPSIDAE

Genus **Hemigrapsus**

KEY TO SPECIES

A.	Legs smooth and free from hairs; hands spotted.	1.	*H. nudus*

AA.	Legs smooth but hairy; hands not spotted.	2.	*H. oregonensis*

1. Hemigrapsus nudus (Dana) Rathbun.	PURPLE SHORE CRAB
(FIGS. 1, 2, 3, 9)

Pseudograpsus nudus Dana; *Heterograpsus nudus* Stimpson; *Hetero-grapsus sanguineus* Kingsley; *Brachynotus nudus* Holmes.

Rostrum none. Antennae short, inconspicuous. Carapace roughly rectangular, anterior part convex and undulated; posterior margin straight except at each end where it is concave to make a place for the attachment of the last pair of walking legs; front of 2 lobes with comparatively broad and shallow emargination; the 2 prominences behind the front about evenly rounded; 3 teeth on the anterior lateral margin counting the post orbital one as the first, first 2 markedly convex, the last very much smaller and less prominent than the others; surface of the carapace smooth, punctate, curved line of white pits from the H-shaped depression in the center to the last antero-lateral tooth. The line of teeth or granulations on the pterygostomian region run practically parallel to the antero-lateral margin and are larger and farther apart on the posterior end of the line. Maxillipeds punctate with round edge on inner margin of ischium and merus. Chelipeds large, powerful; merus trigonous with rounded projections at distal end; carpus with prominent projection on inner surface; hands smooth, inflated; fingers toothed; large patch of long soft hairs on the inner palms of the chelipeds of the males. Predominating color reddish purple flecked with dirty white; hands always spotted.

Often great variation in color is noted; some are green and black without any indication of purple, while others are reddish brown; often there are large irregular spots of dirty white on the carapace and in 4 instances the whole carapace save for a tiny spot on the posterior margin, was dirty white. This great variation in color and markings was noted only among the smaller specimens, yet many of these were sexually mature and were carrying eggs. One of those bearings eggs was 15 mm. wide and 14 mm. long; the carapace of the largest found was 37 mm. long, 41 mm. wide. They are abundant everywhere along the shore below the high tide line. Some hide under rocks and stones and others run about under the algae out from the shore. On several occasions they were found on the piles under the Friday Harbor docks (4).

2. **Hemigrapsus oregonensis** (Dana) Rathbun. HAIRY SHORE CRAB (FIG. 8)

Pseudograpsus oregonensis Dana; *Brachynotus oregonensis* Holmes.

Very similar in general characteristics to *H. nudus*. Carapace of the same general shape with the characteristic smooth and punctate surface; front with four lobes, the median ones being more prominent; the prominences behind the front are more noticeable than in *H. nudus*. There is the same H-shaped depression with white pits extending in a curved line to the last antero-lateral tooth; the ridge on the pterygostomian region has fewer but larger teeth. Chelipeds large and smooth with the exception of the merus which has a row of fine hairs on the upper and lower edges of the inner side; the flat rounded projection on the distal end of the merus and the rounded projection on the inner side of the carpus are both present; males have a patch of soft hairs on the inside of the hand; dactyl and pollex somewhat roughened on the inner edge but no prominent well defined teeth. Walking legs hairy, particularly on upper margins; dactyls grooved, with rows of short hairs between ridges; more slender than in *H. nudus*. Color gray with bluish-black markings; the walking legs have numerous groups of tiny spots, while the carapace is more or less mottled with larger blotches of color; ventral surface of hands and dactyls very much lighter in color, dirty white.

More or less variation of color was observed in these, especially among the smaller specimens. As in *H. nudus,* some are almost wholly white. Many of these small mottled ones were bearing eggs, and varied in width from 8 to 12 mm. And in length from 7 to 10 mm. These were collected from June 25 until July 1. The largest specimen collected measured 31 mm. wide and 28 mm. long.

The coast line from Point Caution (1) to Argyle Bay (14) on San Juan Island was carefully examined and *H. oregonensis* was found abundantly on the fine sandy and muddy portions of the coast line, but it became less abundant as sandy and muddy flats merged into rocky portions and finally disappeared altogether; Newhall's Lagoon (6), Argyle Lagoon (13) and McDonald's beach (3) contained great numbers of them.

Family PINNOTHERIDAE

KEY TO GENERA

A. Dactyls of last pair of walking legs markedly longer than those of preceding pair.   PINNOTHERES (p. 360)

AA. Dactyls of last pair of walking legs not longer than those of preceding pair.

B. Third pair of walking legs markedly longer and stouter than those of preceding pair.   PINNIXA (p. 361)

BB. Third pair of walking legs very little longer and stouter than those of preceding pair.   SCLEROPLAX (p. 362)

Genus **Pinnotheres**

KEY TO SPECIES

A. Carapace soft; walking legs increasing in length posteriorly.

1. *P. pugettensis*

AA. Carapace hard; walking legs not increasing in length posteriorly.

2. *P. concharum*

1. **Pinnotheres pugettensis** Holmes   (NOT FIGURED)

"Carapace soft, smooth, subpentagonal.   Front triangular, acute curved downwards, scarcely protruding beyond the general contour of the carapace.   Orbits nearly circular.   Antennae shorter than one-half the width of the front.   Maxillipeds very oblique, strongly pubescent; merus narrower than in *nudus,* the outer margin convex; penultimate joint broad, subquadrate, distally truncated, last joint minute, joined slightly in advance of the middle of the preceding one but scarcely reaching beyond the tip.   Chelipeds smooth; merus short, the upper margin furnished with long hairs; hands narrow, elongated, rounded, smooth, the dactyls and inner side of the palm short, pubescent; fingers subcylindrical, nearly straight, a little shorter than the palm, the tips strongly hooked, dactyl with a low tooth near the base of the inner margin.   Ambulatory legs slender, increasing slightly in length posteriorly; propodi hairy above and below; dactyls narrow, compressed, convex above, abruptly contracted near the tip into a short, curved claw; in the three anterior pairs the dactyls are shorter than the propodi and leave the lower margin nearly straight; in the last pair the dactyl is much longer than the preceding propodus, much longer than the preceding dactyls, and has the lower margin concave. The outer surface of the palm is brownish with light colored reticulations.

Length of carapace, 10 mm.; length of first ambulatory legs 9.5 mm. Width of carapace, 10.5 mm.; length of last ambulatory leg, 10.5 mm." (Holmes, 1900.)

Reported from Puget Sound region in the branchial cavity of *Halscynthia* by Miss Rathbun.   Found in the Friday Harbor region by Prof. Kincaid.   No specimens were found by the writer.

2. **Pinnotheres concharum** Rathbun, in forthcoming work. (NOT FIGURED)

Cryptophrys concharum Rathbun, in Proc. U. S. Nat. Mus. 16:250. 1893.

"Carapace smooth, slightly longer than broad; a faint sulcus behind the gastric region but no longitudinal sulci as in (*C.*) *pubescens*. Front emarginate. Antennules large, nearly transverse. Ocular peduncles short, stout and completely filling the orbits. Antero-lateral margins marked by a ciliated line. Sides of the carapace broadly rounded. Merus of the maxillipeds with the outer margin curved, the distal portion almost transverse; the last joint of the palp four-sided, the extremity widened. Chelipeds and ambulatory legs margined by a row of coarse hairs. Ambulatory legs widened and quite strongly compressed; second pair a little longer than the others; fourth pair over reaching the carpus of the preceding pairs; dactyls short, terminating in slender, curved, corneous tips. Abdomen in the male widest at the second joint; the large, compound segment has the margin at first convex and then slightly concave; the two following segments broader than long; terminal segment subrectangular but distally rounded; the last two segments may be partly coalesced. Length, 4.7 mm.; breadth, 4.2 mm." (Holmes, 1900.)

The specimens have been found in Friday Harbor region by Professor Kincaid. No specimens were found during the summer of 1916. Miss Rathbun has reported that they are found in the mantles of *Mya arenaria, Cardita borealis* and *Mytilus edulis.*

Genus **Pinnixa**

KEY TO SPECIES

A. Dactyls of third pairs of walking legs straight.   1. *P. tubicola*

AA. Dactyls of third pairs of walking legs curved.   2. *P. littoralis*

1. **Pinnixa tubicola** Holmes.   (FIG. 13)

Rostrum none; antennae small, inconspicuous; carapace smooth, more than twice as wide as long, strongly curved and bent downwards, both laterally and anteriorly; "a shallow, transverse depression behind the gastric area, behind which is a convex (not crested) transverse intumescence from which the carapace curves sharply downwards, towards the broad, slightly concave posterior margin. Front short, deflexed, not projecting beyond the general contour of the carapace"; maxillipeds pubescent; fringe of hair on the anterior margins on either side of the eyes. Chelipeds short but rather stout; merus with a rounded plate-like projection at the distal end on the inner surface; hand inflated; dactyl and pollex slightly hooked, inner margin meeting when closed. First pair of walking legs slender; merus long, about equal to the combined length of propodus and

carpus; dactyls slender.   Second pair of walking legs longer and stouter than the first pair.   Third pair of walking legs considerably longer and stouter than any of the others; dactyl short and thick.   Fourth pair of walking legs shortest of all, their distal ends not extending beyond the merus of the third pair.   Color golden brown with spots of bluish gray on dorsal surface.   Much lighter and of uniform color on ventral surface. The carapace measured 16 mm. wide and 7 mm. long.

Found in burrows of sandworms on Newhall's beach (5) and on Brown Island opposite the Marine Station (8).

Three females carrying eggs were found on July 3, 1916.

2. **Pinnixa littoralis** Holmes.   (FIG. 14)

Carapace flattened; width greater than length; surface smooth, without tubercles or hairs; front truncated, with a well defined median groove; the posterior portion to the median line curves to meet the posterior margin.   Chelipeds large, smooth; hands long, over one-half the length of the whole cheliped, somewhat inflated; pollex short, inclined downward, with a notch at the distal end into which the tip of the curved dactyl fits; when the dactyl closes against the pollex the inner margins do not meet as in *P. tubicola,* but a somewhat rounded opening is found between them. Walking legs more slender and nearer the same size than in *P. tubicola;* third pair stoutest and longest; distal end of fourth pair extending slightly beyond the merus of the third pair; dactyls stout, distally curved at the tips.   Color grayish-white and often with brownish tipped walking legs. The carapace measured 5 mm. wide and 3 mm. long.

Found in the mantle cavities of *Macoma nasuta, Mya arenaria* and the cockle.   On the sandy beach on Brown Island opposite the Marine Station (8) and McDonald's beach (3).

<div align="center">Genus Scleroplax</div>

1. **Scleroplax granulata** Rathbun.   (FIG. 15)

Pinnixa (Scleroplax) granulata Holmes.

Carapace sub-orbicular, strongly convex, "curving downwards towards all the margins"; surface not marked by any prominent sulci, some showing just faint indications of the median sulcus and others no indications at all, punctate, devoid of any hairy covering, slightly granular near the margins.   Orbits small, circular, with a very narrow interorbital space.   Distal joints of maxillipeds fringed with long curved hairs.   Chelipeds of male larger and longer than those of female, hand also more inflated than in female; hands of both sexes granulated, slightly pubescent; dactyl strongly curved; pollex slightly inclined downward but not curved. Walking legs long, slender, not markedly unequal; dactyls long, slender,

almost as long as propodi. Color grayish white, very much darker after moultings. The carapace measured 11 mm. wide and 8 mm. long.

Found at low tide on Newhall's beach (5) in the mantle of *Mya arenaria.*

Family CANCRIDAE

KEY TO GENERA

A.   Whole margin toothed with serrate edges; body covered with stiff hairs and bristle-like scales.   TELMESSUS (p. 363)

AA.   Posterior lateral margin not toothed; body not covered with hairs nor bristle-like scales.   CANCER (p. 364)

Genus Telmessus

1.   **Telmessus cheiragonus** (Tilesius) Rathbun.   HERMIT CRAB (FIG. 17)

Cancer cheiragonus Tilesius; *Telmessus serratus* White; *Polycorystes ambiguus* Brandt; *Cheiragonus hippocarsinoides* Brandt; *Cheiragonus cheiragonus* Ortmann.

Rostrum none, but a deep median depression in the inner antennal front and a smaller notch in the top of each division, making 4 triangular subequal teeth which extend forward about the same distance; long, stout, bristle-like hairs attached to this margin make it somewhat difficult to see these conditions from the dorsal side, but they can be seen clearly from the ventral side.   Antennae short.   Carapace helmet- or pentagonal-shaped, with a margin of 6 large projecting teeth; the 3 anterior teeth are bordered with 2 tiny spines; the fourth lateral tooth is very large, projecting out as far again as the other marginal teeth, curving less towards the anterior surface; the anterior surface of this fourth lateral tooth is roughened by 4 tiny spines, 1 near the point of the tooth and the other 3 evenly spaced ones separated from the tiny outer one, the 2 posterior marginal teeth are smaller and have entire margins; surface of carapace undulated or deeply areolated, covered with broken transverse rows of notched setae-scales and short, stiff, bristle-like hairs; some of the smaller specimens show no bare areas, but larger ones show small, irregular bare spots on either side of the median line near the center of the carapace, other bare spots are noted anterior to and lateral to these; posterior lateral margin bordered with longer and stiffer hairs than anterior lateral portion.   Hands with longitudinal rows of spines on dorsal surface; carpus spiny, hairy, with 1 very large sharp spine on the dorsal side at the distal end; dactyls darkened for more than half their length, armed with heavy tubercular teeth.   Walking legs hairy, scaly, the hairs and scales arranged in transverse rows as on the carapace but farther apart; hairs on legs longer than on carapace; dactyls slender and longer than the propodi, marked with longitudinal grooves, slightly curved at the tip, the

ridges between the grooves marked by little rows of stiff hairs. Color varying from a yellow-brown to dark red. The propodi and dactyls and some portions of the carapace show the red distinctly.

Found along shore at low tide and in shallow water. Not abundant. Three specimens were found in Argyle Lagoon (13) and a few at 6 fathoms between Turn Island and San Juan Island (10); also some off Canoe Island (16); one on the south end of Brown Island (8) and a few along the shore from Madrona Point (7) to Minnesota Reef (11).

Genus Cancer

A.   Front of 5 teeth; carapace much wider than long.

B.   Front of 5 subequal teeth, greatly produced; dactyls of chelipeds black on inner margin for almost the whole length; lobes of margin of carapace not spine-tipped.   1. *C. productus*

BB. Front of 5 unequal teeth, not produced; dactyls of chelipeds not dark colored, white-tipped; lobes of margin of carapace spine-tipped.

C.   Carapace surface finely tubercled; spine outside of second antennae large, blunt; hands with longitudinal rows of roughened tubercles; dactyls of last pair of walking legs flattened.
                         2. *C. magister*

CC. Carapace surface smooth; spines outside of second antennae very small; hands with slight indications of ridges, but neither roughly tubercled nor spiny; dactyls of last pair of walking legs not flattened.   3. *C. gracilis*

AA. Front not of 5 teeth; carapace sub-orbicular.   4. *C. oregonensis*

1. Cancer productus Randall.   EDIBLE CANCER CRAB (FIG. 19)

Platycarcinus productus Gibbes; *Cancer perlatus* Stimpson.

Carapace wide for its length; antero-lateral edges margined by 10 teeth, the last 3 or 4 with acute tips which point to the anterior; closed fissures between the marginal teeth mark the carapace; interorbital portion of carapace extending forward more than the other parts and is one of the distinguishing characteristics of this species; carapace somewhat tubercled but not so uniform as in other species; female higher through the median line than the male. Chelipeds large, powerful, more ridged longitudinally in the adult than in the young; inner ridge of carpus projecting forms a large tooth at the distal end, another large tooth on the margin near the hinge which is opposite the rounded elevation on the hand; inner edge of dactyl darkened almost to proximal end, outer edge darkened about one-half the distance. Dactyls of walking legs with longitudinal ridges

and a fringe of hairs on dorsal and ventral edges. Most *C. productus* are dark red above and very much lighter below, but great variation is often found among the young and immature. Some are a mottled mixture of blue-black and tan, while others are grayish in color, and streaked with irregular lines of a bluish shade. Those lines are referred to by some writers as "zebra like."

Quite numerous on sandy and muddy shores, occasionally along rocky shores. They are found from the low tide line to a depth of several fathoms. In Argyle Lagoon (13); in McDonald's beach (3); on piles under Friday Harbor docks (4).

2. **Cancer magister** Dana.   EDIBLE CANCER CRAB (FIG. 18)

Metacarsinus magister Milne-Edwards.

This is very similar to *C. productus* in all general features; body is longer for its width than in *C. productus.* Antero-lateral teeth not so deeply indented, quite spiny, particularly the last 3; last tooth the largest, forming quite a sharp projection; whole dorsal surface covered with very fine tubercles, the larger on the elevations of the carapace; carapace convex, quite hairy on ventral side; 3 median interorbital teeth small, separated by a space from the larger outer ones; outer ones not reaching so far forward. Chelipeds large and powerful; inner margin of dactyls and pollex marked with pronounced elevations; hand with 5 longitudinal ridges, upper margin cut into a number of sharp teeth; carpus reticulate, with sharp spine on inner margin at distal end; merus with spine on distal end and another a short distance below it. Dorsal and ventral edges of walking legs much rougher than of *C. productus;* dactyl and propodus of last pair of walking legs quite flat and paddle-like. Color much more dull than in *C. productus.*

There is little contrast between these crustaceans and the sandy bottoms where they are found abundantly. Many were found in Argyle Lagoon (13) and McDonald's Cove (3). They are found with *C. productus.*

3. **Cancer gracilis** Dana.   GRACEFUL CANCER CRAB (FIG. 16)

Carapace quite roughened but not pubescent; ventral surface of body not so hairy as other forms of *Cancer.* Antero-lateral margin bordered with teeth; lateral margins with a slight notch posterior to the last lateral tooth; interorbital margin very much the same as in *C. magister.* Chelipeds comparatively smooth; hands with few roughenings but no definite rows of teeth or tubercles; dactyl and pollex much as in *C. magister;* there are two spines on distal end of merus, 1 over the inner angle and the other just below it. Walking legs clean, slender, graceful. General color gray or tan dotted with red.

One male secured by means of a trawl between the north end of Brown Island and San Juan Island (2) had irregular spots of tan all over the carapace. They are abundant in Argyle Lagoon (13) and can be collected at low tide with a dip net. They are also found in the channel between the north end of Brown Island and San Juan Island (2) on a muddy bottom at 11 fathoms.

4. Cancer oregonensis (Dana) Rathbun.   HAIRY CANCER CRAB (FIG. 23)

Trichocera oregonensis Dana; *Trichocarcinus oregonensis* Holmes; *Trichocarcinus walkeri* Holmes.

Rostrum none; interantennal margin grooved, 2-lobed. Antennae mostly short, hairy, longest hairs on inner margin and at the base. Eyestalks with small tooth on anterior surface; teeth on the margin serrate and pointing towards anterior, alternate ones are more acute, first sharp one is the third from the front. Carapace round, without distinction between anterior and posterior lateral margins as in most *Cancer* species; surface very irregular, more deeply areolated in mature than immature specimens; fringe of hairs about the posterior part of carapace more noticeable in young specimens. Chelipeds large, claws dark colored; hands and carpus with longitudinal rows of tiny elevations, the most dorsal one on the hand has the largest elevation; carpus with 2 spines at distal ends, 1 on the dorsal side, the other on the inner side and somewhat below it. Walking legs quite hairy; some with light spots which tend to give the legs a somewhat banded appearance. Color dark red above, lighter beneath.

Those dredged off west side of Shaw Island showed considerable variation in color. In some a very irregular band of orange or yellow extends across the carapace anterior to the cardiac groove. The whole carapace is more gray and is more or less spotted. In some the median line from the posterior end to beyond the cardiac groove shows very gray.

Found at extreme low tide buried in mud and fine sand under rocks, at 6 to 55 fathoms. They are very abundant on the gradual rocky slopes on the northeast corner of Brown Island (8), but become very scarce below this point on the whole eastern side until the southeast corner is reached. Even here they are not numerous as at the northeast corner. A few were found on the southeast corner of Brown Island (8). Also found at Turn Rock (12); beach between Marine Station (5) and Friday Harbor Cannery (4); Newhall's beach (5); channel between Turn Island and San Juan Island (10); and all the rocky points from Madrona Point around to Argyle (14).

Family PILUMNIDAE

Genus Lophopanopeus

1. Lophopanopeus bellus (Stimpson) Rathbun. BLACK-CLAWED CRAB
(FIG. 22)

Xantho bella Stimpson; *Xanthodes hemphillii* Lockington; *Xanthodes hemphilliana* Lockington; *Lophoxanthus bellus* Milne-Edwards; *Lophozozymus bellus* Miers; *Lophoxanthops bellus* Holmes.

Rostrum none. Front sinuate with median notch. Antennae short, inconspicuous. Antennules folding obliquely. Carapace broader than long, broader than anterior part, flattened behind, convex in front with 2 prominent notches at the junction of the anterior lateral and posterior-lateral margins; teeth small, posterior one smaller than the anterior ones; not pubescent or tubercled but cut with irregular sulci which make a distinctly areolated surface. Chelipeds strong and powerful; hands rounded on upper side more or less inflated, carpus roughened on dorsal side with 1 prominent tubercle on distal end near dorsal edge on the inside; merus with few irregular teeth on upper margin at distal end. Dactyls and propodi of walking legs hairy; carpus short, bilobed on upper surface; merus with acute upper edge. Anterior part of carapace either reddish-brown or purplish; posterior portion marked with gray; legs are colored much the same as carapace but spotted considerably with gray; occasionally chelipeds are almost white but usually are same in color as carapace; dactyls always black; ventral surface a dull gray, much lighter than the dorsal surface.

Considerable variation in shades noted among them. Next to *Hemigrapsus nudus* they show the most variation of our species. The most variation was found among those along the beach from Madrona Point (7) to the beach west of Turn Island. *L. bellus* like *Cancer oregonensis* is found buried in sand and mud under rocks on rocky shores. The two were always found in the same places. They were collected on Brown Island (8) at the northeast and southeast corners, and at the south end; rocky points from Madrona Point (7) to Argyle Bay (14); Minnesota Reef (11), Marine Station (5) to Cannery dock (4); off northeast corner of Brown Island (8) in 20, 52 and 55 fathoms.

Family MAIIDAE

KEY TO GENERA

A. Rostrum long, slender.

B. Carapace with prominent spines on branchial region.

CHORILIA (p. 368)

BB. Carapace without prominent spines on branchial region.

OREGONIA (p. 369)

AA.   Rostrum short, broad.
    C.   Merus of walking legs long in some, not distinctly flat, not distinctly broader near base.
        D.   Carapace (with rostrum omitted) sub-rectangular.
            E.   Carapace smooth; postocular spine not prominent.
                                      EPIALTUS (p. 369)
            EE.   Carapace not smooth but tubercled; postocular spine more prominent.   PUGETTIA (p. 370)
        DD.   Carapace (with rostrum omitted) not sub-rectangular.
            F.   Rostral horns not convergent.   SCYRA (p. 371)
            FF.   Rostal horns convergent.   HYAS (p. 371)
    CC.   Merus of walking legs long, quite flat, distinctly broader near base.
                                      CHIONECETES (p. 372)

Genus **Chorilia**

1.   **Chorilia longipes** Dana.   (FIG. 24)

Hyastenus (Chorilia) longipes Miers; *Hyastenus japonicus* Miers.

"Carapace pyriform, inflated and covered with sharp spines of unequal size. Median region tumid, with two median spines and a row of three spines on either side, the posterior one being the largest and situated a little behind the middle of the interval between the two spines on the middle line; a prominent spine on the tumid hepatic region; several small spines on the cardiac region and a small spine or tubercle near the posterior end of the intestinal. The spines on the branchial regions are numerous and variable, but there is usually a more prominent spine near the middle. Pterygostomian regions with a row of teeth or spines. Rostrum long, the horns nearly straight, pubescent and divergent. Preorbital spine prominent, acute, postorbital acute and pointing obliquely downwards. Basal antennal joint armed at its external angle with a slender spine, the margin behind which is armed with two smaller spines. There may be a few minute spinules at the apex of the eyestalk. Merus of the chelipeds furnished with small tubercles, which are more prominent on the angles; carpus furnished with small tubercles on the outer side, which are more or less plainly arranged in 3 or 4 rows; hands long, slender, compressed, palm sub-carcinated above, nearly smooth and generally having a small tubercle on the outer side near the articulation; fingers long and slender. Dactyls of the slender ambulatory legs long and nearly straight. Abdomen of the male tapering from the third segment, the last joint longer than broad and rounded at the tip. Abdomen of the female broadly elliptical, the joints increasing in length from the third to the last. In some females, either immature or sterile, the abdomen is narrowly elliptical and not nearly so wide as the thoracic sternum. The

legs and many parts of the body are covered with a short pubescence"
(Holmes, 1900).

This has been found in the vicinity of Friday Harbor but not during
the summer of 1916. Miss Rathbun reports that it ranges from depths of
27 to 603 fathoms.

Genus Oregonia

1. **Oregonia gracilis** Dana.   DECORATOR CRAB (FIG. 20)

Oregonia hirta Dana; *Oregonia longimana* Bate.

Rostrum bifid; in males two-thirds the length of the antennae, longer
than in the females. Carapace triangular in shape; sparsely covered with
stiff hooked hairs and roughened by minute tubercles; "median, cardiac and
branchial regions tumid"; postorbital spine sharp, curved toward anterior
of carapace, some distance below orbit, more noticeable in males than in
females; the partition between the antennulary pits is produced forming
a spine. Chelipeds slender, very long in adult males; meruś sometimes
longer than the rostral horns, subcylindrical, covered with tubercles and
setose hairs; carpus rounded, roughened; hands with a more or less ir-
regular row of roughened tubercles on the upper margin; fingers longi-
tudinally grooved, gaping at base in adult males. Walking legs long,
slender, subcylindrical, sparsely covered with setose hairs; dactyls long,
sickle-shaped, ending in corneous tips. Color tan or gray, with dots and
small markings of red. Color cannot be seen until decorative material
is removed.

There is such a marked difference in the general appearance of the
males and the females that some have been led to describe them as two
species. In the males the legs are much longer, the chelipeds stouter and
with a deeper depression at the base, and the body more slender. The
females are thicker in the post cardiac region, and the body and legs more
hairy. They are found at all depths from low tide to 55 fathoms and
possibly greater depths. They are particularly abundant on the old piles
of the Friday Harbor dock (4), the eelgrass (*Zostera marina*) off Brown
Island (8) and the beaches east side of the Marine Station (5); also
found off the northeast corner of Brown Island (8); off Canoe Island
(16); between Turn Island and San Juan Island (10); off Minnesota
Reef (11).

Genus Epialtus

1. **Epialtus productus** Randall.   BIG KELP CRAB (FIG. 25)

Rostrum bifid; horns short, broad at the base, inner margins slightly
concave and outer slightly convex; in younger specimens the hooks at distal
end extend inwards; hairs are present on inner lateral margins and dor-
sal surfaces of the rostral horns, disappearing in older ones from both

margin and dorsal surface. Supraorbital and postorbital spines not prominent. Carapace exclusive of rostrum more or less rectangular; carapace higher thru median line in young ones; posterior margin markedly convex in the middle, lateral margins broken by 2 prominent teeth; surface smooth and not areolated. Chelipeds large and powerful in all males except very old ones, shorter than the first pair of walking legs; fingers long, slender, in females dentate along the whole inner margins but not so in males. Walking legs long, smooth, stouter than those of most spider crabs; dactyls with two rows of fine teeth along inner margins terminating in a sharp curved claw, teeth projecting toward tip of leg. Adult female carapace measured 70 mm. in width from tip to tip of second pair of lateral teeth, and 85 mm. in length from notch in rostrum to posterior margin; similarly male carapace measured 70 mm. in width and 87 mm. in length. Color of dorsal parts dull brownish green, of ventral parts light tan; sternum, mouth parts and chelipeds often marked with bright red; body often mottled with spots of darker color.

Abundant everywhere in the region in eel grass (*Zosteria marina*), on kelp, and on the piles under docks; common to at least 40 fathoms.

Genus **Pugettia**

1. **Pugettia gracilis** Dana.   GRACEFUL KELP CRAB (FIG. 21)

Pugettia lordii Bate; *Pugettia quadridens gracilis* Ortmann.

Rostrum bifid; the divergent horns broad at base and tapering to a point, inner margins and dorsal surfaces covered with stiff hooked hairs. Antennae short; flagellum extending a short distance beyond rostrum. Carapace lyrate; surface very uneven. Most of the elevations or tubercles tipped with a tiny tuft of hairs, in many these tufts not conspicuous; with 2 short rows of hooked setae on each side of the median line posterior to the supraorbital spine, with two rows of similar setae from the posterior part of the rostrum to the anterior edge of the supraorbital spine; anterior margin of supraorbital spine fringed with hairs; postocular spine and first lateral tooth united to make a leaf-like expansion of carapace; third lateral tooth on posterior part of lateral margin. Chelipeds smooth; hands large; fingers shorter than the palm; gaping at the proximal ends in older specimens; dactyl and pollex not toothed alike; carpus marked with 3 or 4 lines; merus roughly trigonous, upper edge more or less toothed. Largest specimen collected was a male 67 mm. long and 45 mm. wide. Color of dorsal surface usually greenish brown, and ventral side very much lighter. But those found off Canoe Island (16) in Upright Channel among red algae are a brilliant red. A few red ones were also found in the channel between Turn Island and San Juan Island (10).

Abundant everywhere in the region in eel grass (*Zostera marina*), on kelp, and on piles under docks; common to at least 40 fathoms.

Genus Scyra

1. Scyra acutifrons Dana.   SHARP-NOSED CRAB (FIG. 27)

Rostrum bifid; horns short, broad, leaf-like, tapering to points that diverge. Antennae short, not much longer than the rostrum. Supraorbital spine small, inconspicuous. Carapace pyriform, with very irregular surface; a conspicuous H-shaped depression breaks up the surface into several prominent elevations, producing a small acute anterior tubercle in the median region and a larger, more rounded one just posterior to it; branchial regions tumid with large rounded tubercles, anterior to them are elevations which may bear small tubercles; another large blunt tubercle near the posterior margin in the median line. Chelipeds much larger in male than in female; merus elongated, rounded above, flattened on lower side, surface very much roughened with prominent tubercles; carpus rough, more or less reticulate with tubercles; hands elongated, very acute on upper surface, particularly in old males; middle portions of hand more or less inflated, surface granulated; fingers deflexed, toothed on inner edge, in old males gaping considerably at the base. Walking legs more or less subcylindrical, quite pubescent; dactyls with sharp corneous tips much shorter than propodi. Great variations occur in surface of the carapace due to the age; tubercles are usually smoother in females and rougher and more prominent in old males. Color dull, usually gray or tan with more or less red on chelipeds and walking legs, usually body so encrusted with bryozoans that it is difficult to see the color. Like other spider crabs, they are usually covered with a variety of decorative materials. Sponges, hydroids, and bryozoans are used by them more than algae.

Miss Rathbun reports them to range from low tide to 40 fathoms, but none was found near the tide lines anywhere in the vicinity. They were found off the northeast and east side of Brown Island (8) in 20 to 55 fathoms. On July 7, 1916, 2 females were taken with eggs. Not particularly abundant.

Genus Hyas

1. Hyas lyratus Dana.   LYRE CRAB (FIG. 26)

Rostrum bifid; horns broad at base, tapering to points that curve inward, forming hooks at the ends. Antennae short, not extending far beyond the rostrum, the 2 basal joints constituting one-half their length; with 2 calcareous knobs on the ventral surface just below and at the side cf the base. Carapace with leaf-like expansion formed by union of 2 anterior lateral spines posterior to the eye; leaf-like expansion with outer

margins long and somewhat concave, surface rough and beset with more or less regularly arranged tubercles and hooked hairs; branchial region rounded at the middle, marked by a prominent line of rounded tubercles; the posterior lateral margin of the carapace with a row of rounded tubercles beneath which is a row of hooked hairs; median line throughout whole length consisting of varying elevations beset with groups of tubercles. Carapace often covered with hydroids, algae and barnacles; merus of chelipeds long, sub-trigonous, beset with tubercles which are particularly prominent along the angle lines; carpus somewhat roughened; hands compressed, usually with a granulated upper margin; fingers grooved, smooth on the edges, their inner margins finely toothed. Walking legs subcylindrical, somewhat hairy; dactyls long, corneous tipped. Color of carapace reddish gray; legs banded with stripes of red and gray, not so noticeable in mature specimens. Red is present on the legs of mature specimens, but does not extend to the tips except in the chelipeds. Body much lighter on ventral surface.

Found in 6 to 55 fathoms. They were secured in the following places: between Turn Island and San Juan Island (10) in 6 fathoms; channel north of Brown Island (2) in 11 to 13 fathoms; off Canoe Island (6) in 20 to 30 fathoms; off northeast end of Brown Island (8) in 55 fathoms.

Genus **Chionecetes**

1. Chionecetes tanneri Rathbun.   DEEP-SEA SPIDER CRAB (FIG. 28)

Rostrum very short, thick, bifid, curved slightly upwards at tip. Eyes partially protected by orbit, toothed on ventral side. Carapace suborbicular, very irregular with roughened tubercles; with few hairs; tubercles smaller and more spine-like near the anterior; lateral margins spiny. Chelipeds quite rough; hands rounded, with longitudinal rows of tubercles on dorsal side, these not so evident on the ventral side; carpus rough but tubercles not arranged in distinct rows, merus long, rough with large spiny tubercles on the inner edge at the distal end; fingers long, slender, light-tipped, longer than the palm, grooved on ventral side from proximal end to over one-half the length of dactyl, inner margins finely tubercled and fitting close together. Walking legs very long, much flattened; merus one-half or more of the length of the legs, of the last pair rounded and the whole leg very much smaller than the others.

No specimens were secured during the summers of 1915 and 1916. The description was made from a museum specimen which was not in very good condition. Professor Kincaid says that they have been secured in Griffin Bay.

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GLOSSARY

Acicle: A scale.

Acuminate: Tapering to a point; pointed.

Ambulatory: Used for walking.

Arcuate: Bent or curved like a bow.

Areolated: Divided into small divisions.

Basipodite: Second joint of appendage of decapod.

Bifid: Cleft to the middle or slightly beyond, cleft.

Branchial: Region posterior to cervical groove and over the branchiae or gills.

Buccal: Pertaining to the mouth.

Carpus: The wrist; third joint from the distal end of a decapod appendage.

Cervical groove: A groove on the dorsal surface which extends downwards and forwards and marks the union of head and thorax.

Clavate: Club-shaped; shaped like a baseball bat.

Corneous: Horny.

Coxopodite: First joint of thoracic appendage of a decapod.

Dactyl: Last joint of a decapod appendage; the claw.

Deflexed: Bent abruptly downward.

Distal: Farthest from the body.

Divergent: To proceed or extend in different directions from the same point.

Emarginate: The margin interrupted by notches or shallow sinuses.

Epistome: The region between the mouth and antennules.

Exopodite: The outer of the 2 branches of a typical decapod appendage.

Eye-peduncles: Eyestalks.

Foramen: An opening.

Fosette: A cavity.

Hepatic region: These areas are anterior to the cervical groove and at the sides of the gastric region.

Hispid: Rough with bristles or minute spines.

Infraocular: Below the eyes.

Interorbital: Between the orbits.

Intumescence: State of being swollen or enlarged.

Ischiopodite: Same as ischium.

Ischium: Basal joint of endopodite; fifth joint counting back from the distal end of an appendage with all parts present.

Lyrate: Lyre-shaped.

Maxillipeds: The first 3 thoracic appendages.

Merus: Fourth joint counting back from distal end of the thoracic appendage.

Natatory: Used for swimming.

Orbicular: Round or nearly so.

Palm: The basal portion of the hand.

Palp: The last 2 or 3 small terminal joints of either branch of the maxillipeds.

Pleopod: An abdominal appendage.

Pollex: The immovable finger of a cheliped.

Propodus: The second joint from the distal end of the thoracic appendage of a decapod.

Proximal: Near or towards the body; opposed to distal.

Pterygostomian region: Portion below lateral margins on either side of the mouth area.

Pubescent: Covered with short soft hairs or down.

Punctate: With minute depressions or pits.

Pyriform: Pear-shaped.

Serrate: Notched on the edge like a saw.

Seta: Any slender, more or less rigid, bristle-like structure.

Sinuate: Having the margin alternately curved inward and outward; wavy.

Spatulate: Spoon-shaped.

Spiniform: Thorn-like.

Sternal plastron: The ventral portion of the thorax.

Styliform: Having the form of or resembling a style, pin, or pen.

Sub: Almost, nearly or somewhat.

Subcarcinate: Somewhat keeled.

Subequal: Almost equal.

Sulcus: A groove.

Suture: The line of junction of contiguous parts that seem to have grown together.

Trigonous: 3-angled.

Truncate: Ending abruptly as if cut off transversely.

Verges: The male intromittent organ of any of the invertebrates.

PLATE 80

Fig. 4.   Petrolisthes eriomerus. $\times$ 0.66.

Fig. 5.   Cryptolithodes typicus. $\times$ 0.66.

Fig. 6.   Hapalogaster mertensii. $\times$ 0.66.

Fig. 7.   Phyllolithodes papillosus. $\times$ 0.66.

Fig. 8.   Hemigrapsus oregonensis. $\times$ 0.66.

Fig. 9.   Hemigrapsus nudus. $\times$ 0.66.

Fig. 10.   Acantholithodes hispidus. $\times$ 0.66.

Fig. 11.   Rhinolithodes wosnessenskii. $\times$ 0.66.

Fig. 12.   Lopholithodes mandtii. $\times$ 0.66.
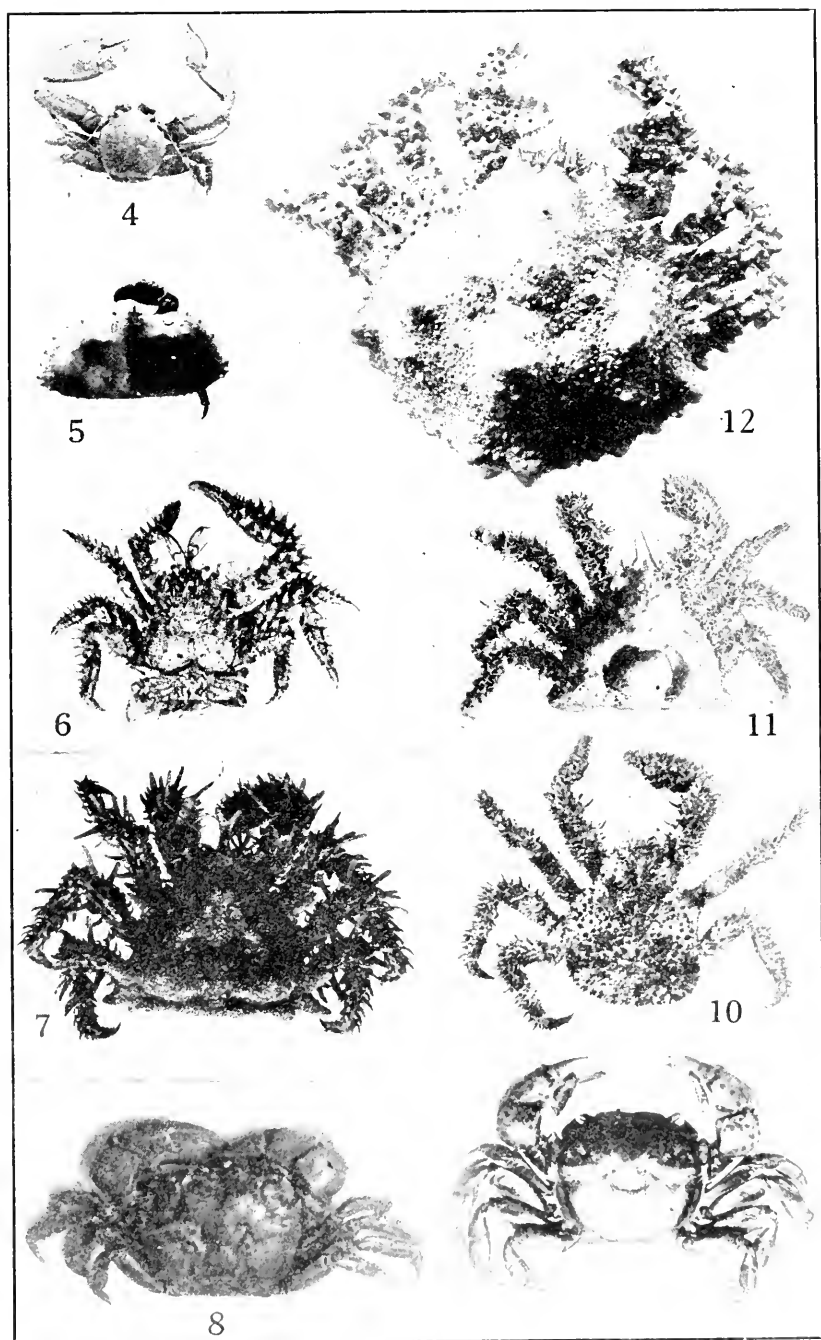
PLATE 80

PLATE 81

Fig. 13.   Pinnixa tubicola. $\times$ 1.

Fig. 14.   Pinnixa littoralis. $\times$ 1.

Fig. 15.   Scleroplax granulata. $\times$ 1.

Fig. 16.   Cancer gracilis. $\times$ 0.5.

Fig. 17.   Telmessus cheiragonus. $\times$ 0.5.

Fig. 18.   Cancer magister. $\times$ 0.33.

13

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18   19
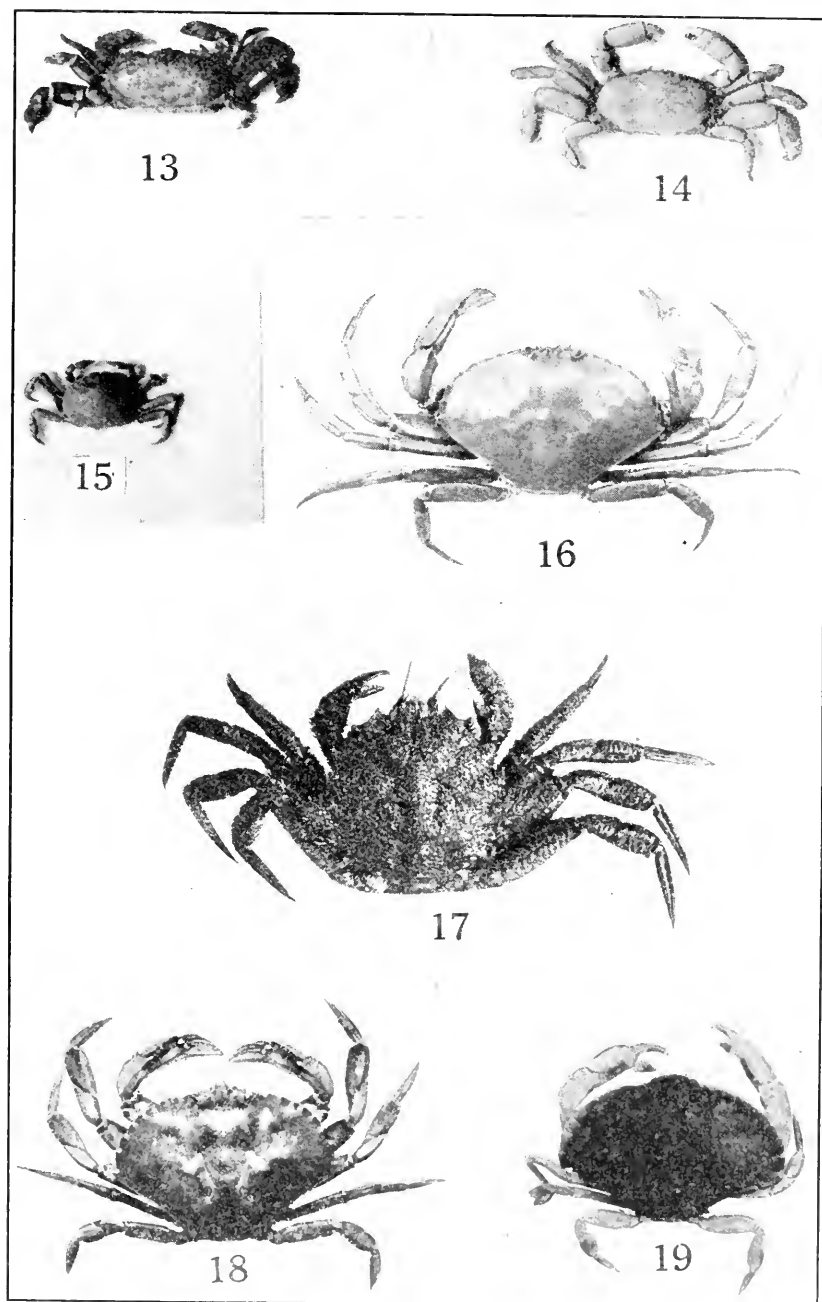
PLATE 81

PLATE 82

Fig. 19.   Cancer productus. $\times$ 0.33.

Fig. 20.   Oregonia gracilis. $\times$ 0.5.

Fig. 21.   Pugettia gracilis. $\times$ 0.5.

Fig. 22.   Lophopanopeus bellus. $\times$ 0.66.

Fig. 23.   Cancer oregonensis. $\times$ 0.33.

Fig. 24.   Chorilia longipes. $\times$ 0.66.

Fig. 25.   Epialtus productus. $\times$ 0.33.

Fig. 26.   Hyas lyratus. $\times$ 0.5.

Fig. 27.   Scyra acutifrons. $\times$ 0.66.

Fig. 28.   Chionectes tanneri. $\times$ 0.5.

PLATE 82

INDEX TO NO. 30

North Pacific Coast Species of Desmarestia

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Comparatively little work has been done upon the genus *Desmarestia*, although it is one of the most widely distributed of the marine algae, several species are easily available, its structure is most interesting, its method of reproduction has long been a matter of doubt, and its systematic position is still unsettled. Descriptions of some of the species are given in the earliest botanical works of England and the Continent; Kützing (11) and Thuret (30) early began the study of its structure and reproduction; but the first important contribution, other than taxonomic, was that by Söderström (28) on the anatomical structure of *D. aculeata*. Rosenvinge (24) and Kuckuck (10) established the method of reproduction, and Jönsson (8) published a scholarly article on the structure and development of the thallus. Oltmanns (20) gave a brief summary of what was then known of the genus, and Skottsberg (27) gave a very good discussion of the Antarctic species.

These are perhaps the most important articles dealing directly with the genus. A painstaking student, with good library facilities, will find many references to the genus, or to one or more of its various species, but the great majority of these are taxonomic or deal with geographical distribution; many of them are in monographs not widely circulated; many are extracts from more general articles, and others are mere incidental references. It has seemed to the writer, therefore, that it would not be an unnecessary duplication of labor to take up a detailed study of the genus, especially of those species found on the north Pacific coast, summarizing the literature, assembling what is already known of distribution, growth habit, structure, and reproduction, and adding to the work already done the results of her own observations and study. The present article is merely a preliminary statement to be followed within a few months by a more detailed account.

The genus *Desmarestia*, so named by Lamouroux (12) in honor of A. G. Desmarest, a celebrated French naturalist and professor of zoology, at first consisted of the 3 common European species, *D. aculeata* (L.) Lamour., *D. viridis* (Muell.) Lamour., *D. ligulata* (Lightf.) Lamour., and the Pacific coast *D. herbacea* (Turn.) Lamour. To this list, as a result

of numerous exploring expeditions, especially those in Antarctic regions, others have been added from time to time, until, according to De Toni (4), the genus consists of 14 species and 4 varieties. Of these only one, *D. media* (C. A. Agardh) Grev., in addition to the 4 already named, has been reported from the north Pacific coast; but Okamura (19) has proposed a new Pacific species, *D. tabacoides,* which may occur on American as well as Japanese shores.

The Desmarestias are all sublittoral, growing from just below low tide line to a depth of 20 to 25 fathoms. They occur most abundantly in cool temperate and polar regions, and are not found in the tropics. In northern waters, according to Kjellman (9) and Muenscher (17), they occur usually as secondary species in the Laminaria association, or in deeper water just below the Laminarias, but in antarctic and sub-antarctic regions they form the dominant sublittoral vegetation, being as abundant, according to Skottsberg (27) as are the Laminarias in arctic regions. They prefer exposed situations in strong currents, but sometimes flourish in quieter waters. In still water or on exposure to the air they soften, change color, and decompose rapidly.

There are 2 types of thallus in the Desmarestias: (a) the filiform, in which the main axis and all its branches to the last order are slender and terete or only slightly flattened, with the axial filament and its surrounding tissues, the so-called midrib, not at all evident from the surface, as in *D. media;* (b) the plane type, in which the main axis and all its branches are much flattened, with a very evident midrib, as in *D. herbacea.* The plant rises from a simple disk-shaped or flattened-conical holdfast. The plant body consists of an axial row of articulate cells, surrounded by layers of more or less differentiated tissue and covered by a cortical layer from one to several cells thick. According to Oltmanns (20), the Desmarestias may be likened to a huge *Ectocarpus* with a cortical growth, finding its analogy in the corticated Callithamnions. The main axis bears branches to the fifth and sixth degrees and during the growing season all the branches and branchlets are tipped by confervoid branching filaments, whose cells are densely filled with small lens-shaped chloroplasts. According to Söderström, these filaments function as assimilation organs during the season of rapid growth.

The growing region is intercalary, and located at the bases of the hairs, which are thus continuous with the axillary row of cells in the older parts of the plant. Branches appear on the axis both above and below the growing region, and cortication begins at most only a few cells back of this point, so that the lateral branches which arise below the growing region appear on superficial examination to be lateral outgrowths from the corticated thallus.

At the end of the period of elongation these hairs are shed, and development and differentiation of the tissues surrounding the axial filament take place. The summer condition of the plant, therefore, does not at all resemble the spring condition. In fact, plants collected in spring and summer are so unlike that at first they were classified as different species, when the only differences consisted in the presence or absence of these transitory hairs.

The period of reproduction seems to occur during the winter months, living swarmspores having been seen by Kuckuck (10) at the beginning of December, and by Rosenvinge (24) in February. So far as known, reproduction occurs only thru asexual spores, formed in unilocular sporangia, which occur in sori on the surfaces of the branches and are developed from cortical cells, altho Johnson (7) reports having seen spores formed in the cells of the terminal hairs of *D. ligulata.*

The genus *Desmarestia,* according to Setchell and Gardner (26), is represented on the north Pacific coast by 5 species, *D. aculeata* (L.). Lamour.; *D. aculeata* f. *media* (Ag.) J. Ag., or *D. media* (C. A. Ag.) Grev.; *D. viridis* (Muell.) Lamour.; *D. ligulata* (Lightf.) Lamour.; and *D. ligulata* f. *herbacea* (Turn.) J. Ag., or *D. herbacea* (Turn.) Lamour. These species have all been reported from the San Juan Islands, and the present study is based upon material collected during the summer of 1916, while the writer was a research student at the Puget Sound Marine Station, located on San Juan Island, one of the largest of the San Juan group.

DESMARESTIA ACULEATA (L.) Lamour., under various names, is included in practically every list of marine algae collected in northern European or British waters, back to the earliest published accounts. Tournefort (31) describes it as *"Fucus tenuifolius, foliis dentatis."* The species name is credited to Linnaeus, who published it first in the second edition of his Species Plantarum (15). Lamouroux (12) was the first to classify it as *Desmarestia aculeata* Linn., and his reference (13) is the earliest found by the writer reporting it from the north Pacific (Kamchatka).

D. aculeata was probably the first member of the genus to be recognized and described by the early systematists. It is also the most widely distributed species, and seems to be at least fairly common thruout its entire range. It is not surprising, then, that it has received more attention than other members of the genus, and that its structure, as worked out by Kützing (11), Reinke (22), and especially by Söderström (28) and Jönsson (8), should be considered as typical.

Söderström was the first to undertake a detailed study of this species, giving in his carefully worked out paper the origin and development of the various tissues of the plant. He was the first to distinguish between

the active growing period of early spring, when elongation of the thallus takes place, and the period of differentiation of tissues which immediately follows and continues throughout the summer.

During the dormant period the plant has a stiff, ragged appearance, due to the shedding of much of the previous season's growth. At the beginning of the growing season, which varies with the latitude, new shoots appear, many of them arising adventitiously in the axils of old branches, or of the stubs which remain when the old branches are shed. The older parts of the plant are hard and leathery, and dark brown in color, but the new growth is soft and flaccid and a yellowish brown, becoming harder and darker as the growing season advances. Plants in the winter condition, or the older parts of plants that have grown for several seasons, are quite hard and rigid, and do not show the characteristic softening and change of color; but the young branches of plants collected during the summer change color and decompose quite rapidly.

Desmarestia media (Ag.) Grev. was first published by C. A. Agardh (1) under the name of *Sporochnus medius,* habitat Unalaschka. It is the *D. intermedia* of Postels and Ruprecht (21), and held specific rank under various names until reduced to a variety of *D. aculeata* by J. G. Agardh (2). Since that time some writers have followed Greville, others Agardh, until about 1895, possibly thru De Toni's "Sylloge Algarum" (4), Agardh's classification seems to have become fixed in the literature.

Börgeson (3) says of Faeröese specimens that "the typical var. *media* differs rather widely from typical *D. aculeata,* and consequently it might perhaps more properly be regarded as a distinct species." Setchell and Gardner (26) consider their Pacific coast specimens to be so distinct from the ordinary typical *D. aculeata* that they "are sorely tempted to restore them to specific rank."

According to the writer's observations, the plants have not the adventitious branching so characteristic of *D. aculeata;* neither main axis nor branches are flattened, as is the case in the type species; according to practically every description by various authors, the branches are almost all opposite, while in the type species the branches are all alternate. Moreover, the plant body is lighter in color and softer in texture; and not merely the young and tender branches but the whole plant body shows the characteristic softening and change of color on exposure to the air or when allowed to stand for a short time in a vessel of water, either salt or fresh.

With so many differences in appearance and habit, the writer feels that there is no justification for subordinating *D. media* to *D. aculeata.* She therefore proposes that this plant be restored to specific rank, under the name *Desmarestia media,* first published by Greville.

DESMARESTIA VIRIDIS (Muell.) Lamour., first published in the Flora Danica (16), was reported from British waters by Stackhouse (29), altho it had been known to collectors for several years previously. It was first reported from the Pacific coast by Postels and Ruprecht (21), and according to Harvey (6) it was found at Esquimalt and Fuca Strait by David Lyall.

J. G. Agardh (2) distinguishes between the Atlantic and Pacific forms, the latter being wider and evidently compressed. Saunders (25) says that on the Alaskan coast it is not uncommon, but less abundant than *D. aculeata*. He does not mention *D. media,* with which *D. viridis* is often confused. Setchell and Gardner (26) are in doubt as to the occurrence of the species in the region under discussion, because its resemblance to *D. media* and "lack of careful study of the 2 forms make it uncertain at times to which species the references refer."

Muenscher (18) says that "young specimens of this form (*D. aculeata* f. *media*) have been reported as *D. viridis*. A careful comparison with both *D. viridis* and *D. aculeata* shows that they probably all belong to the latter, at least none of them possess the characteristics of *D. viridis*."

The writer has examined Miss Tilden's herbarium specimens No. 353 of *D. viridis* collected at Minnesota Reef, San Juan Island, and Saunders' No. 274 from Prince William Sound, and has compared them with herbarium specimens and preserved material in her own collection. All the material examined seems to belong to the same species, and answers the descriptions of various authors given for *D. media.* When compared with specimens of *D. viridis* from the Atlantic coast, the difference is plainly evident. Material collected by Holden (Phyc. Bor. Am. 11) on Penfield Reef, Long Island Sound, is much more delicate than any Pacific coast material the writer has seen, having the truly capillary and exactly opposite branching emphasized by European writers and so clearly shown in herbarium specimens of Hauck and Richter's Phykotheka universalis (No. 123) and Rabenhorst's Algen Europa's (No. 1741). Moreover, it is the consensus of opinion of European writers that *D. viridis* is an annual, and it is so considered at the Marine Biological Laboratory at Woods Hole. Specimens of Pacific coast plants collected for the writer are undoubtedly perennial. Individuals over 100 cm. in length, collected in April, have branches of the 5th and 6th orders, and show the hairs of the transitory spring growth just beginning their development.

So far as can be decided by examination of mature plants, the writer is of the opinion that the occurrence of *D. viridis* on the Pacific coast of North America is not yet established, and that the plants from this region reported as *D. viridis* are in all probability *D. media.*

Desmarestia ligulata (Light.) Lamour. was first reported by Light-foot (14). Altho known to all the early European collectors, it was not found on American shores, according to Harvey (6), until collected by Lyall on the coast of British Columbia.

Setchell and Gardner (26) seem doubtful of the authenticity of their specimens, but material collected for the writer at Kanaka Bay on the exposed side of San Juan Island could not possibly be confused with the var. *herbacea* of authors (*Pl. 84, Fig.* 1). Its color, size, growth-habit, width of frond, in fact its whole general appearance, mark it as a distinct type.

Desmarestia herbacea (Turn.) Lamour. This beautiful species, brought from the northwest coast of North America by Menzies, was first published by Turner (32) under the name *Fucus herbaceus.* His description and plate are still the best things in literature concerning this plant, and his argument for considering it a distinct species is still valid, in the opinion of the writer. It was so considered for many years after its discovery, until reduced to a variety of *D. ligulata* by J. G. Agardh (2).

It is one of the largest of the brown algae outside of the Laminariaceae. Setchell and Gardner (26) report that it has been found cast ashore at Esquimalt. B. C., in fragments several meters long, and full 30 cm. wide. According to Rigg (23), it sometimes reaches a length of 2.4 or 3 meters and a width of from 30 to 40 cm., although it is usually much smaller. Several fragments of plants secured for the writer by means of a trawl measured from 40-60 cm. across the widest part of the main axis. and 1 fragment of a plant raised while gathering specimens of *Nereocystis* was about 3 meters long and a trifle more than 100 cm. wide. This huge flat thallus when first taken from the water was more than a millimeter in thickness, crisp and easily broken if bent, and dark brown in color. Within 3 or 4 hours after it was collected it had assumed the characteristic greenish color of exposed plants, had become as thin as paper, and was so soft and easily torn that it could not be handled.

If this extreme difference in size were not enough to distinguish *D. ligulata* and *D. herbacea* as distinct (separate) species, the color and texture of specimens, whether fresh, preserved in formalin, or dried for herbarium use, is entirely different.

The writer proposes, therefore, that the *D. ligulata* var. *herbacea* (Turn.) of J. G. Agardh be restored to specific rank under the name *D. herbacea* (Turn.) Lamour.

Desmarestia tabacoides Okam. This species, proposed by Okamura (19), is not mentioned elsewhere in literature. Okamura describes it as follows: "Fronds very large, leaf-like, shortly stipitate, with broadly oval, very usually obliquely lobed. simple. midribbed, and coriaceous

lamina. The midrib is slightl yprominent below. but gradually becoming fainter upwards, with opposite veins which dissolve, even from the base, into numerous fine veinlets." The description is accompanied by an excellent plate, and a discussion of the reproduction.

While looking over a haul of material secured for the writer by means of a trawl several young plants in various stages of development were found (*Pl.* 84, *Figs.* 2-6) which differ markedly from young plants of *D. herbacea* brought up in the same haul. These plants are much broader, round off abruptly at the base to a very short stipe. and are without lateral branches; while in the young plants of *D. herbacea* (*Pl.* 83, *Figs.* 1-4) the thallus is comparatively narrow, tapers down very gradually to the stipe, and lateral branches are well developed on very small specimens. These new plants seem to correspond closely with Okamura's description, and the writer feels safe in adding this interesting new species to the Desmarestias of the north Pacific coast of North America.

After a careful study of material collected in the San Juan Islands, from whose waters have been reported all the species of *Desmarestia* supposed to occur on the north Pacific coast, and a comparison of this material with descriptions, plates, and herbarium material of American and European collectors, the writer reaches the following conclusions:

1. *D. aculeata* (L.) Lamour. is a fairly common species. It is easily identified by its habit of adventitious branching and by the dark brown color and hard texture of the older parts of the plant body. Only the younger branches are discolored on exposure.

2. *D. media* (C. A. Agardh.) Grev. is entitled to specific rank. It is very abundant and can be distinguished from *D. aculeata* very easily by its lighter color and softer texture, and by its behavior on exposure, the whole plant body changing color, becoming flaccid. and rapidly decomposing.

3. *D. viridis* (Muell.) Lamour. probably does not occur in this region.

4. *D. ligulata* (Lightf.) Lamour. is rare, but easily identified on account of its narrow thallus, yellowish brown color, firm texture. and comparatively small plant body.

5. *D. herbacea* (Turn.) Lamour. is entitled to specific rank. It is a very abundant species, at least in the Puget Sound region, and is unmistakable on account of its large size. It discolors quickly, and becomes very flaccid and easily torn on exposure, and when dried becomes thin and papery, and does not adhere to paper.

6. *D. tabacoides* Okam. is a new species recently reported from the Japanese coast, and is here reported from American shores for the first

time. Not enough specimens have been collected to determine the maximum size, and it has not been collected when bearing the assimilating hairs. So far as known, this species is distinguished by its extreme width in proportion to length, by the abrupt rounding off of the base of the thallus, and by a lack of branches.

The following is a modification and extension of Muenscher's (18) treatment of the genus:

DESMARESTIA Lamour.

Plants filamentous or compressed or merely much flattened to blade-like, pinnately branched, coriaceous or membranaceous, solid. Central strand or axis composed of one or several rows of elongated cells surrounded by larger long cells and smaller round cells; cortical layer composed of somewhat rounded cells; tips of young branches ending in a delicate pinnately branched filament. Reproduction very little known; unilocular sporangia known only in some species, developing directly from cortical cells.

KEY TO NORTH PACIFIC SPECIES

A. Branches much flattened, blade-like, with a mid-rib.
  B. Blades narrow, gradually tapering at base, firm in texture; plant body comparatively small.   *D. ligulata*
  BB. Blades up to 100 cm. broad, gradually tapering at base to a short stipe, thin and easily torn when dry; plant body very large.
                                                                  D. herbacea
  BBB. Blades broad, abruptly rounding at base to a short stipe; branches few or none; plant body small.   *D. tabacoides*
AA. Branches terete or compressed, not flattened.
  C. Branches compressed, alternate, coriaceous, many arising adventitiously.   *D. aculeata*
  CC. Branches terete, almost all opposite, cartilaginous.   *D. media*

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PLATE 83

Desmarestia herbaeea: all $\times$ ½.

Fig. 1.   Very young plant, branches just appearing.

Fig. 2.   Fragment of young plant, base and apex missing.

Fig. 3.   Young plant, branches of first order well developed.

Fig. 4.   Young plant, branches of second order well developed.

Fig. 5.   Basal portion of mature plant.

PLATE 83
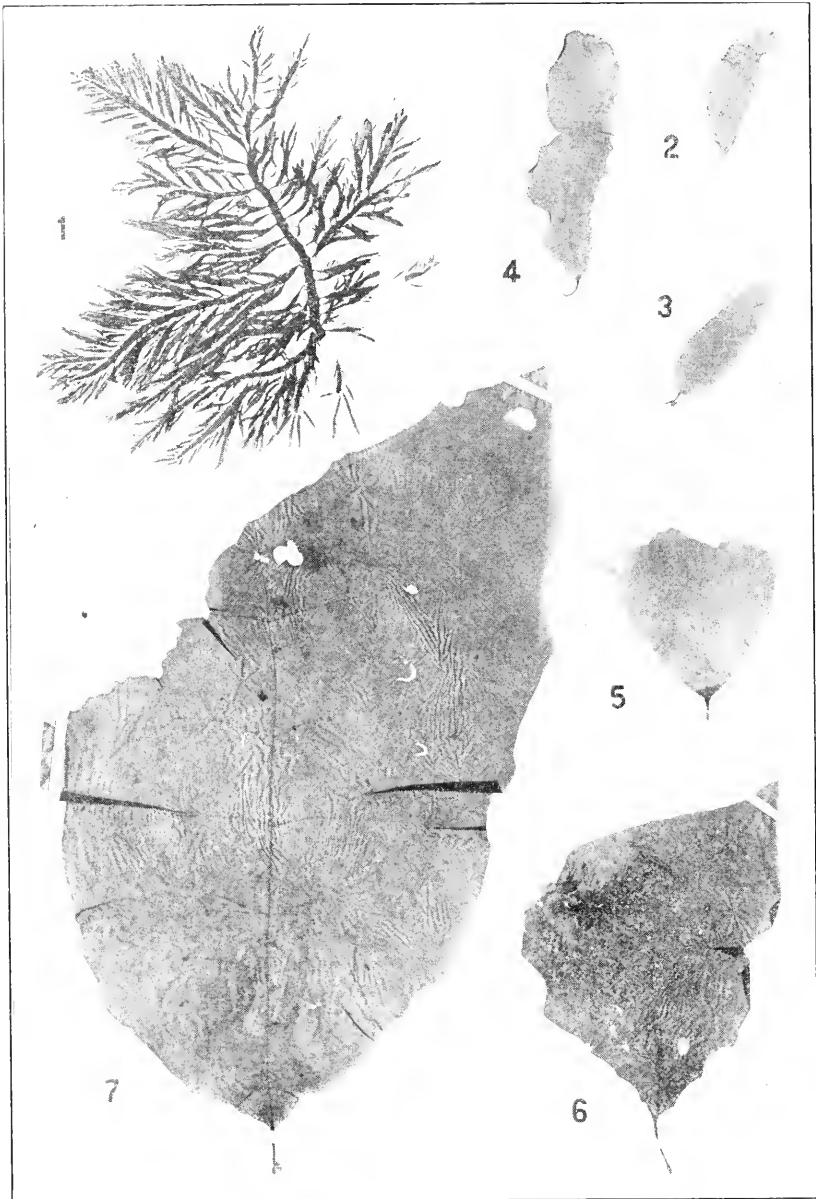
PLATE 84

Fig. 1. Portion of mature plant of *Desmarestia ligulata.* $\times \frac{1}{2}$.
Figs. 2-7. Successive stages in the development of *Desmarestia taba-coides.* $\times \frac{1}{2}$.

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The plant names in **boldface type** are either new or new combinations.